Final Report

Odor Reduction Analysis and Study
Kingston Wastewater Treatment Facility
City of Kingston, New York

April 2003

Stearns & Wheler Companies

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April 23, 2003

The Honorable James Sottile
Mayor, City of Kingston
City Hall
420 Broadway
Kingston, NY 12401

Re: Final Report - Odor Reduction Analysis and Study
City of Kingston Wastewater Treatment Facility
S&W No. 20224.0

Dear Mayor Sottile:

Stearns & Wheler is pleased to submit our final report of Odor Reduction Analysis and Study for the City of Kingston Wastewater Treatment Facility. In our final report, we have incorporated comments received from Mr. Dennis Larios, P.E., and Mr. John C. Kwak, P.E., City Engineer. At the request of Mr. Stephen Finkle, the City's Economic Development Director, we are forwarding twenty-five bound copies, one unbound copy, and one electronic copy on CD for your use.

Stearns & Wheler looks forward to assisting the City of Kingston in the implementation of these recommendations for reducing odors at the City's wastewater treatment facility. We will contact you to identify a mutually convenient time for us to begin planning details of the project scope and schedule for these improvements.

If you have any questions in the interim, please contact us.

Very truly yours,

STEARNS & WHELER, LLC

Bruce G. Munn, P.E., DEE
Senior Associate

BGM/dlr

Enclosure

cc: Dennis Larios, P.E., Brinnier & Larios, PC (w/enc.)
Robert Bowker, Bowker & Associates, Inc. (w/enc.)
John C. Kwak, P.E., City of Kingston (w/out enc.)

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ODOR REDUCTION ANALYSIS AND STUDY
KINGSTON WASTEWATER TREATMENT FACILITY
CITY OF KINGSTON, NEW YORK

Prepared for

CITY OF KINGSTON, NEW YORK

Prepared by

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Project No. 2022410

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The Kingston wastewater treatment facility (WWTF) was initially constructed in 1946 to serve the municipal wastewater treatment needs of the City. Since 1946, the City has completed several major capital improvements projects at the plant to expand capacity and upgrade the level of wastewater treatment provided. Major plant upgrades and the years in which they occurred are summarized as follows:

1970-1974	Upgrade from primary to secondary (biological) wastewater treatment and installation of mechanical sludge dewatering (vacuum filter) system to replace sludge drying beds.
1994	Expansion of plant capacity from 4.8 to 6.8 mgd, installation of fine bubble diffused aeration system for activated sludge aeration, replacement of vacuum filter with belt filter press for sludge dewatering, replacement of grit removal equipment and mechanical bar screens, and replacement of effluent chlorination system with ultraviolet disinfection system.

The plant currently provides advanced wastewater treatment for seasonal ammonia removal utilizing a single-stage diffused air activated sludge system. In accordance with the current basis of design, the City is authorized to discharge up to 6.8 mgd of treated wastewater to Rondout Creek on a maximum 30-day average basis in accordance with the conditions of SPDES Discharge Permit NY-0029351, issued by the New York State Department of Environmental Conservation (NYSDEC).

Waterfront redevelopment efforts initiated by the City for the area immediately surrounding the wastewater treatment facility site have focused attention on odor concerns at the plant. In response to these concerns, the City retained Stearns & Wheler in September 2002 to perform an odor reduction and analysis study for the plant. The findings, conclusions, and recommendations resulting from this study are presented herein.

1.2 PURPOSE

The purpose of this study was to identify and quantify the magnitude of sources of odors at the Kingston WWTF and to develop recommendations to eliminate the migration of odors off site so as to not have a negative impact on the surrounding area.

1.3 SCOPE OF SERVICES

The scope of services provided by Stearns & Wheler in performing the odor reduction and analysis study for the Kingston WWTF included the following:

1. The Stearns & Wheler project team conducted a site visit on January 10, 2003. In addition, available information was collected, compiled and analyzed to assess current plant operating conditions. Observations from the site visit and analysis of available data are presented in Chapter 2.

2. Representatives from the consulting firm of Bowker & Associates, under contract with Stearns & Wheler, performed an inventory of odor emissions at the plant on October 10-11, 2002. The results of the odor emissions inventory are presented in Chapter 3.

3. Air dispersion modeling was performed by Bowker & Associates to estimate the magnitude of odor emissions for each of the sources identified from the odor emissions inventory. The model results were then used to rank odor sources in order of magnitude. The air dispersion model results and ranking of odor sources are presented in Chapter 3.

4. Alternatives to reduce or eliminate odor sources were evaluated by the Stearns & Wheler project team. This evaluation included an initial screening of odor control options followed by an economic evaluation of feasible alternatives. The results of these evaluations are presented in Chapter 4.

5. Based on the results from evaluation of odor control alternatives, recommendations were developed to address the various sources of odors identified at the plant. Preliminary

design information, budgetary capital and annual operation and maintenance cost estimates, and a proposed implementation schedule were developed for the odor control recommendations and are presented in Chapter 5.

CHAPTER 2

DESCRIPTION OF EXISTING FACILITIES

2.1 GENERAL

The Kingston WWTF is located at 91-129 East Strand Street in the southeast section of the City of Kingston. As shown on Figure 2-1, the facility site (approximately 2.5 acres) is bordered on the south by East Strand Street and is fully developed with little room available for further expansion. The City has targeted the area surrounding the wastewater treatment facility for waterfront redevelopment efforts. In connection with these redevelopment efforts, increasing attention and concern has been focused on odors originating from the wastewater treatment facility. Neighboring properties include a trolley museum, condominiums, restaurants, and other commercial establishments. The nearest neighbors to the facility are located 100 feet from the nearest treatment units.

2.2 INTERCEPTOR SEWERS AND FORCE MAINS

Wastewater is conveyed to the facility for treatment from four main sources as follows:

1. The Rondout interceptor inverted siphon (24-inch diameter pressure sewer) conveys sanitary sewage and combined stormwater and sanitary sewage from approximately 80 percent of the City of Kingston. The area served by the Rondout interceptor includes a portion of the City (approximately 30 to 40 percent) that is served by combined sanitary/storm sewers. Connections to the Rondout interceptor are made at four locations: (a) the Wilbur Avenue diversion chamber; (b) the Broadway diversion chamber; (c) the Hasbrouck Avenue diversion chamber; and (d) the Hunter Street diversion chamber.

2. An 8-inch diameter low pressure force main that parallels the Rondout interceptor inverted siphon along Abeel Street and East Strand. This force main serves the area situated below the gradient of the Rondout interceptor and discharges directly to the entrance chamber at the Kingston WWTF.

3. A 15-inch diameter interceptor sewer that conveys sanitary sewage from the Ponchockie area of the City. This interceptor conveys sanitary sewage to a pump station located at the Kingston WWTF site. The pump station, in turn, pumps the sewage to the entrance chamber.

4. A 12-inch diameter force main from the Sleightsburg Pump Station, which serves the Port Ewen Sewer Improvement Area in the Town of Esopus. This force main discharges directly to the entrance chamber at the Kingston WWTF.

The Rondout interceptor inverted siphon is a likely contributor to odors at the Kingston WWTF. The pressure sewer covers a distance of nearly 2 miles and includes sections comprised of 20-inch diameter steel pipe, 24-inch diameter steel pipe and 24-inch diameter reinforced concrete pipe. At design flow conditions (5 mgd at the point of discharge to the Kingston WWTF), flow velocities range from 1.48 to 2.88 feet per second.

Facility representatives estimate that flow from the Rondout interceptor currently represents approximately 40 to 50 percent of the total wastewater flow received at the Kingston WWTF. Based on flow records for the 1-year period of September 2001 through August 2002, the flow conveyed via the Rondout interceptor is estimated at 1.6 to 2 mgd for average daily flow conditions and 5 to 6 mgd for peak flow conditions. The average detention time in the siphon is estimated at approximately two to three hours.

At normal daily flow conditions, flow velocities in the Rondout interceptor likely fall well below the minimum velocity of 2 to 3 feet per second required to keep solids in suspension. Resulting low flow velocities in the interceptor are insufficient to keep solids in suspension during normal and low flow conditions. Biological decomposition of the settled solids under anaerobic conditions in the pressure sewer produces hydrogen sulfide and other odorous compounds that are released to the atmosphere when the sewage enters the facility. Corrosion of concrete and steel piping that comprise the interceptor sewer, as well as concrete and steel structures and piping at the Kingston WWTF, are also a concern since hydrogen sulfide reacts with water to form sulfuric acid.

2.3 WASTEWATER TREATMENT

A simplified process flow schematic illustrating wastewater and sludge treatment systems provided at the Kingston WWTF is presented in Figure 2-2. As shown, wastewater treatment includes the following:

- raw sewage screening and grit removal
- primary settling
- fine bubble diffused air activated sludge aeration
- secondary settling
- effluent disinfection by ultraviolet radiation

Facility influent monitoring data for the 1-year period of September 2001 through August 2002 are summarized in Table 2-1. The average daily flow recorded over the 1-year period of record was 4.0 mgd. The maximum monthly average flow recorded over the 1-year period of record was 4.8 mgd for May 2002. This flow represents approximately 70 percent of the permitted facility capacity (6.8 mgd). Influent wastewater characteristics appear to be typical for municipal sewage with average $CBOD_5$ and suspended solids (TSS) concentrations of 155 mg/l and 144 mg/l, respectively.

The Rondout interceptor sewer and force mains from the Sleightsburg Pump Station and the on-site pump station serving the 15-inch interceptor sewer discharge to an entrance chamber which houses a mechanically-cleaned bar screen. Turbulence as the wastewater flow passes through the bar screen channel provides the first opportunity for release of wastewater odors to the atmosphere. Ventilation of the building housing the bar screen is exhausted to the atmosphere and is a potential major source of odors at the facility.

After passing through the entrance chamber, sewage is conveyed to a grit tank where relatively quiescent flow conditions allow heavy solids and grit to settle out of the wastewater flow. Solids that settle to the bottom of the grit tank are pumped to a hydrocyclone, where centrifugal force is used to separate the heavy solids from the pumped flow. The heavy solids are discharged to a grit washer, where water is used to wash organic matter from the grit. "Clean" grit is discharged from the grit washer to a dump truck for subsequent hauling to a solid waste transfer station located in New Paltz, owned and operated by the Ulster County Resource Recovery Agency (UCRRA).

Potential sources of odors associated with the grit removal system include the water surface in the grit tank which is exposed to the atmosphere, particularly those areas such as the overflow collection box, where turbulence facilitates stripping of hydrogen sulfide gas and other odorous compounds from the wastewater flow. Other potential sources of odors include the exhaust from ventilation of the enclosure that houses the hydrocyclone and grit washer equipment and the dump truck that is used for temporary storage of grit removed from the wastewater.

Degritted wastewater flows by gravity to the Head House, where a second mechanically-cleaned bar screen is provided. Turbulence as the wastewater passes through the bar screen channel provides a mechanism for release of wastewater odors to the building air space. Ventilation of the bar screen room is exhausted to the atmosphere and is a potential major source of odors.

After passing through the bar screen located in the Head House, the wastewater flow combines with in-plant recycle flows from sludge treatment facilities (gravity thickener overflow, DAF thickener subnatant, anaerobic digester supernatant, and belt press filtrate) and is then spilt to four rectangular primary settling tanks. Exposed water surfaces in the primary settling tanks, particularly turbulent areas including influent flow distribution channels and effluent weir troughs, are potential sources of odors. Based on discussions with the facility operator, the primary settling tanks are operated so that only minimal sludge blankets are maintained. Primary sludge is pumped continuously to a hydrocyclone for degritting. This operating strategy is required for successful degritting and helps to minimize the potential for odors by avoiding deep sludge blankets that can result in anaerobic conditions.

Settled effluent from the primary settling tanks is conveyed by gravity to the settled sewage wet well located adjacent to the operations building. The exposed water surface in the wet well, coupled with turbulent conditions, make the wet well another potential source of odors at the Kingston WWTF.

Settled sewage pumps located in the basement of the operations building pump primary effluent from the settled sewage wet well to three activated sludge aeration tanks. The aeration tanks are equipped with ceramic disk-type fine bubble diffused aeration equipment. Potential sources of odors include those locations where the wastewater is exposed to the atmosphere, i.e., influent flow distribution channels, the surface of the aeration tanks, effluent weirs and the effluent channel.

Mixed liquor from the activated sludge aeration tanks flows by gravity to four rectangular secondary settling tanks. Secondary settling tanks are generally not a primary source of odors at municipal wastewater treatment plants, since odors are generally released at, or prior to, the aeration tanks.

Settled effluent from the secondary settling tanks is conveyed by gravity to channels containing ultraviolet disinfection equipment for effluent disinfection. Because these channels convey wastewater that has been fully treated through advanced secondary treatment for seasonal ammonia removal, the ultraviolet effluent disinfection system is not considered to be a major source of odors at the Kingston WWTF. Effluent from the ultraviolet disinfection channels is discharged to Rondout Creek via two 20-inch diameter outfalls. The lower outfall is used for normal flows and the upper outfall is used for high flows during high tide conditions. This outfall system was constructed in 2000 using City funds as well as grant funding obtained from the NYSDEC.

Analysis of plant performance monitoring data reported by the City for the period of September 2001 through August 2002 indicates consistent compliance with SPDES permit effluent limits as follows:

	SPDES LIMIT	PLANT EFFLUENT (SEPTEMBER 2001-AUGUST 2002)
Monthly average effluent BOD_5	30 mg/l	5 to 13 mg/l
Monthly average effluent TSS	30 mg/l	4 to 15 mg/l
Monthly average effluent UOD	4,890 lb/day (June-October)	1,697 to 3,113 lb/day

2.4 SEWAGE SLUDGE TREATMENT AND DISPOSAL

As shown in Figure 2-2, sludge treatment consists of the following:

- degritting and gravity thickening of raw primary sludge
- dissolved air flotation thickening of waste activated sludge
- anaerobic digestion of combined thickened primary and waste activated sludge
- belt filter press dewatering of digested sludge.

Raw primary sludge is pumped from the primary settling tanks to a hydrocyclone located adjacent to a 20-foot diameter gravity sludge thickener for degritting. Underflow (grit) from the hydrocyclone is discharged to a grit washer for removal of organic matter. "Clean" grit is discharged from the grit washer directly to a dump truck for subsequent off-site disposal at the UCRRA transfer station located in New Paltz. Ventilation of the enclosure that houses the primary sludge degritting equipment is exhausted to the atmosphere and is a potential source of odors at the facility. Another potential source of odors is the temporary storage of the grit removed from the sludge, contained in a dump truck located outdoors.

Overflow from the cyclone degritter (degritted primary sludge) flows by gravity to the gravity thickener. The gravity thickener was constructed in 1971 and has been in service for more than 30 years. Subsequent to construction, a cover was installed on the gravity thickener for odor control. The area under the thickener cover is currently exhausted to a biofilter located adjacent to the thickener.

Based on discussions with the facility operator, the mechanical sludge collector mechanism installed in the thickener is requiring frequent maintenance. During times when the thickener must be taken out of service for repairs, the number of odor complaints received by the facility reportedly increases. Considering the length of time that the thickener has been in service, the mechanism appears to be approaching the end of its useful life. Replacement of the sludge collector mechanism can be expected in the near future, since the typical useful life for mechanical equipment of this type is 20 to 25 years.

Waste activated sludge is pumped to a dissolved air flotation (DAF) thickener to reduce the volume of sludge requiring further treatment (anaerobic digestion and dewatering). The DAF thickener was installed in conjunction with the 1971 plant expansion and upgrade project and has now been in service for approximately 30 years. Dissolved air flotation thickening involves the introduction of air into the waste activated sludge under pressure. When the waste activated sludge is depressurized, the air is released as finely dispersed bubbles that carry the light sludge solids to the surface. The float solids that accumulate on the surface are removed for further treatment and the water removed from the sludge (subnatant) is returned to the facility influent for treatment. By nature, the use of air to float solids to the surface of the DAF thickener results in stripping of odorous compounds present in the sludge. A cover has been installed over the DAF thickener at the Kingston WWTF and the air space under the cover is now ventilated to a package biofilter system for odor control.

Thickened primary sludge from the gravity thickener and thickened waste activated sludge from the DAF thickener are pumped to a two-stage anaerobic sludge digestion system for further treatment. The two-stage anaerobic sludge digestion system is a biological sludge treatment system that reduces the concentration of pathogenic (disease-causing) microorganisms present in sewage sludge. Anaerobic digestion also reduces the mass of solids that need to be disposed by reducing volatile solids and producing methane gas. The two anaerobic digesters were constructed at the time of the original facility construction in 1946. The system was subsequently upgraded in 1984 to install a cogeneration system that utilizes digester gas to produce heat and electricity for in-plant use.

In 1990, a 2-1/2-meter belt filter press was installed at the Kingston WWTF to replace a coil vacuum filter for dewatering of digested sludge. Digested sludge is pumped to the belt filter press, which is located in the operations building. Two roof-mounted exhaust fans are installed for ventilation of the sludge dewatering room. Each exhaust fan has a rated capacity of 2400 cfm providing a design ventilation rate of approximately 18 air changes per hour. As designed, the ventilation system meets current design standards, which require continuous ventilation at a rate of at least 12 air changes per hour for sludge dewatering rooms. However, when the odor emissions inventory was performed on October 1 and 2, 2002, only one of the two exhaust fans was operable. Subsequently, during the project team's site visit on January 10, 2003, neither exhaust fan was operable.

Dewatered sludge is hauled by truck on a contract basis to the UCRRA's solid waste transfer station located in New Paltz for off-site disposal. Facility operating records compiled over the 1-year period of September 2001 through August 2002 (see Table 2-2) indicate that 2,839 wet tons of dewatered sludge were hauled to the transfer station for disposal. The monthly average dry solids concentration of the sludge hauled to the transfer station ranged from 18.9 to 23.4 percent (average of 20.6 percent). Based on the current contract cost of $75 per wet ton, the cost of sludge disposal over the 1-year period of record was $212,925.

2.5 HISTORY OF ODOR COMPLAINTS

The City has received an increasing number of complaints and concerns about odors attributed to the wastewater treatment facility. Discussions with facility personnel indicate that odor complaints typically will increase during those times when the gravity sludge thickener has been out of service for routine maintenance or emergency repairs. Odor complaints, however, are not restricted only to those times when the thickener is out of service. The inverted siphon, which conveys sewage to the facility for treatment, and the proximity of the facility to neighboring residential and commercial properties are also considered to be major reasons for odor complaints. Low flow velocities in the siphon are believed to cause solids deposition in the siphon during average and low flow conditions. Organic matter present in the solids deposits in turn exerts an oxygen demand in the siphon, producing septic conditions in the wastewater treatment facility influent. The septic conditions promote the generation of hydrogen sulfide, and this is believed to have a significant impact on the magnitude of odors observed at the wastewater treatment facility. The proximity of residential and commercial properties to the facility amplifies the concerns about odors and the need for odor control.

2.6 ODOR SOURCES

Hydrogen sulfide is the most commonly known and prevalent constituent of odor emissions from wastewater collection and treatment systems. Hydrogen sulfide has a characteristic "rotten egg" odor, is easily detectable in low concentrations, and can be hazardous to human health and safety when concentrations reach a few orders of magnitude above the limit of analytical detection. Hydrogen sulfide reacts with water to form sulfuric acid, which is corrosive to concrete and metal. Controlling the formation of hydrogen sulfide and other odorous compounds is the main key to controlling odors in wastewater collection and treatment systems.

Based on a review of the Kingston WWTF, discussions with facility operators, and our experience with other municipal wastewater treatment facilities, the following potential sources of odors were identified:

1. Exhaust from ventilation of the entrance chamber structure.

2. Emissions from grit tank and exhaust from ventilation of enclosure for associated cyclone degritting and grit washing equipment.

3. Exhaust from ventilation of the bar screen room located in the Head House.

4. Emissions from exposed water surfaces in the primary settling tanks.

5. Emissions from the settled sewage wet well.

6. Emissions from exposed water surfaces in the aeration tanks.

7. Exhaust from the biofilter that currently treats air ventilated from air space under covers provided for the gravity sludge thickener and dissolved air flotation thickener.

8. Exhaust from ventilation of the belt press sludge dewatering room.

Turbulence in the wastewater flow as it passes through influent bar screen channels and influent and effluent channels for primary settling tanks provides conditions for stripping and release of hydrogen sulfide from the wastewater to the atmosphere.

Sludge blankets in primary settling tanks and the gravity thickener may provide anaerobic conditions, similar to conditions in anaerobic digesters, that promote generation of hydrogen sulfide and other odorous compounds. If sufficient biological activity exists, bubbles may be seen rising from quiescent areas in primary clarifiers. Aerated channels and treatment processes such as the grit tank and aeration tanks can also be the source of odors due to air stripping of odorous compounds from the wastewater.

Sludge dewatering operations can also be a significant source of odors. For plants with anaerobic digesters, the digested sludge can contain relatively high levels of odorous compounds, including hydrogen sulfide, ammonia, and reduced sulfur compounds.

In order to assess the magnitude of odor emissions from the above-mentioned sources, a monitoring program involving air and liquid sampling was developed. The details of this monitoring program and the results obtained are discussed in Chapter 3.

CHAPTER 3

ODOR EMISSIONS INVENTORY, AIR DISPERSION MODELING, AND RANKING OF ODOR SOURCES

3.1 ODOR EMISSIONS INVENTORY

A sampling program was conducted to quantify and characterize odor emissions from known and suspected sources of odors at the Kingston WWTF. Sampling and analysis of air emissions from various odor sources was conducted by representatives of Bowker & Associates, Inc. on October 1 and 2, 2002. A concurrent liquid sampling and on-site analytical program was also implemented. Weather conditions were warm and dry, and there had been no substantial rainfall during the previous few days. The purpose of the sampling program was to develop data for use in estimating the significance of the various odor sources and evaluating means of reducing odor emissions. The descriptions of the air sampling program, analytical procedures, and results are provided in Appendix A.

3.2 DESCRIPTION OF ODOR DISPERSION MODEL

To determine the significance of each of the odor sources at the Kingston WWTF, a screening-level dispersion model was used to estimate the impacts of odor emissions on downwind receptors. Dispersion modeling was accomplished using Trinity Consultants Inc. SCREEN3 Model. SCREEN3 is based on the USEPA Industrial Source Complex - Short Term (ISCST) model and is designed to perform a screening level estimate of downwind pollutant concentrations. SCREEN3 predicts conservative or worst-case estimates of maximum short-term air quality impacts from specific pollutant sources. Modeling is performed within a matrix of 54 variable combinations of wind speed (1–20 m/s) and atmospheric stability class (A–F). Each stability class is based on static stability (related to the change in temperature with height), thermal turbulence (caused by heating of the air at ground level), and mechanical turbulence (a function of wind speed and surface roughness). Using calculated odor emission rates (the product of odor concentration and air flow rate), modeling of the treatment plant was conducted to produce a worst-case estimate of predicted odor concentrations at the nearest receptor.

Ten sources of odor were modeled: first bar rack room (entrance chamber), grit tank, degritter building exhaust, second bar rack room (Head House), primary clarifier quiescent surfaces, primary effluent channel, primary effluent pump station, aeration tanks, biofilter, and belt filter press room exhaust. The distances from the odor sources to the nearest receptor were estimated to be 100 feet for all sources.

3.3 MODEL RESULTS AND RANKING OF ODOR SOURCES

Table 3-1 summarizes the results of the odor dispersion modeling. The SCREEN3 model predicts 1-hour average odor concentration levels as a function of distance downwind from the source. Because odors are often transient and occur for short durations, the results were converted to 1-minute peak values using a power law function reported in the literature. The conversion factor was calculated to be 1.98, and a value of 2 was used.

An odor concentration of 5 to 7 D/T is often used as a target value at the nearest receptor, as odor concentrations above this value have the potential to result in odor complaints. Based on peak measured odor concentrations and worst-case weather conditions (e.g., inversions), all of the odor sources at the Kingston WWTF have the potential for downwind impacts when the nearest receptor is only 100 feet away.

Appendix B includes a figure which shows an example of an "odor decay" curve for the primary effluent pump station. In general, *area* sources show greater off-site impacts than *point* sources having the same odor emission rates. This is because area sources are typically ground level emissions that occur over a larger area, and thus there may be limited dilution and limited rise of the odor plume. A higher odor release point, such as from the roof of a building, allows for greater dispersion. At a receptor distance of 30 meters (m) or 100 feet, the predicted 1-hour average odor level resulting from the pump station exhaust is about 44 D/T. A 1-minute peak level is predicted to be over 80 D/T, which would clearly be perceived as a strong and objectionable odor.

The odor decay curves and output data for all other modeled odor sources may also be found in Appendix B.

The highest predicted odor impacts (one-hour average odor concentration of approximately 30 D/T or greater) are associated with the following sources:

1. Primary effluent pump station.
2. First bar rack room (entrance chamber).
3. Second bar rack room (Head House).

The primary effluent pump station has a relatively low air flow, but a high odor concentration. The first and second bar rack rooms show similar predicted effects on downwind odor levels, and both these sources are considered high priority for control. Given the measured diurnal variations in hydrogen sulfide emissions, raw wastewater sources are likely to have much greater downwind impacts during evening hours.

The "second tier" of odor control priorities had predicted one-hour odor impacts of 7 to 17 dilutions to threshold and consisted of the following sources::

4. Belt press room.
5. Aeration tanks.
6. Primary clarifier effluent launders/channels.
7. Biofilter exhaust.
8. Primary clarifier quiescent surfaces.
9. Grit chamber.
10. Degritter building

Of the second-tier priorities, the belt press room exhaust and the aeration basins are predicted to have the greatest off-site impact. The belt press room should be assigned a higher priority due to the objectionable nature of the odor. However, the belt press room emissions are intermittent, occurring only when biosolids are dewatered.

The aeration tanks also show a relatively high off-site impact due to the higher-than-normal odor concentration. Given that only one sample was taken, it is possible this is an anomaly caused by sampling or analytical procedures. For the modeling, an odor concentration of 1,000 D/T was used. Due to the large surface area of the aeration tanks, the predicted effect on downwind odors is significant. Normally, aeration tank odors are not the primary target for odor control due to the perception that the odor is "less objectionable" than raw wastewater or sludge odors.

It should be noted that these are **1-hour average** odor impacts. Peak short-term odor impacts can be several times the predicted one-hour impacts. Therefore, these sources can potentially result

result in nuisance level odors beyond the fenceline, but are lower priority than the bar rack rooms and primary effluent pump station. The turbulent raw wastewater sources, such as the grit chamber discharge and primary clarifier effluent launders/channels, should also be targeted for odor control since these emissions can increase dramatically during periods of high sulfide loading to the plant.

The modeling of a particular odor source is often based on one or two "grab" samples of odorous air. Odor and hydrogen sulfide emissions can vary widely depending on time of day, upstream industrial activities, wastewater characteristics, and other factors. The odor dispersion model is only a tool to assist in the engineering judgment of what sources need to be controlled. The goal of this effort is not to make the Kingston WWTF "odor-free," but to control the major sources of odor such that they do not create nuisance odor conditions in downwind neighborhoods or at other receptors.

CHAPTER 4

EVALUATION OF ODOR CONTROL ALTERNATIVES

4.1 CHEMICAL CONTROL ALTERNATIVES

Chemicals that can be used to reduce odors associated with wastewater treatment fall into three main categories: chemical oxidants, chemical precipitants, and oxygen additives.

Chemical oxidants that can be used for odor control include sodium hypochlorite, hydrogen peroxide, and potassium permanganate. These chemicals reduce odors by reacting with (oxidizing) odor compounds present in wastewater.

Chemical precipitants include various forms of iron salts such as ferric chloride, ferrous chloride, ferric sulfate, and ferrous sulfate. These chemicals reduce odors by reacting with dissolved sulfide to form an insoluble iron-sulfide precipitate. Because the reaction is specific to dissolved sulfide, iron salts are not effective for reducing odors associated with other compounds.

Sodium and calcium nitrate are also chemicals that can be added to wastewater for odor control. These chemicals add oxygen, in the form of nitrate, to the wastewater. Facultative bacteria prefer nitrate over sulfate as a source of oxygen. As a result, when nitrate is added to wastewater, odor reduction is accomplished by inhibiting the biological conversion of sulfate to sulfide.

Table 4-1 provides a summary of the advantages, disadvantages, and relative frequency of use for the most common chemicals used for odor control. All of these chemicals may be used effectively in controlling odors. None of these chemicals applied in the correct dose/location will have a negative effect on biological treatment or flow/sludge metering equipment. Chlorine addition does have the potential for formation of chlorinated organics, including potential cancer-causing compounds.

Chemical addition to the trunk sewer upstream of the Rondout interceptor sewer inverted siphon is recommended to reduce odors that are released at the entrance chamber at the wastewater treatment plant site, as well as to reduce corrosion within the interceptor sewer and at the treatment plant. City representatives have indicated that chemical storage and feed facilities may be located at the site of the former City incinerator. Chemical feed would be to a major trunk sewer located immediately upstream of the siphon.

It is recommended that the facilities be designed to provide flexibility for use of either sodium hypochlorite or iron salt solutions (ferrous chloride, ferrous sulfate, ferric chloride). Sodium hypochlorite is a very effective odor control chemical, but may result in the formation of chlorinated organics. Iron salts are slightly less effective in reducing odors, but do not form potentially harmful byproducts. Iron does form a solid precipitate which can settle out in the piping downstream of the application point. Sodium hypochlorite addition is preferred due to its ability to reduce odors associated with both hydrogen sulfide and reduced sulfur compounds. In addition, sodium hypochlorite addition does not result in the generation of chemical solids that may accumulate in the Rondout interceptor sewer inverted siphon when flow conditions result in low flow velocities. Further, sodium hypochlorite is effective in preventing the downstream formation of hydrogen sulfide. Due to the physical conditions in the siphon, the majority of the hydrogen sulfide received at the plant influent is believed to be produced downstream of the proposed chemical addition point.

In the future, if odors at the plant headworks persist, consideration may be given to chemical addition for odor control at the other collection system pump stations and force mains including, but not limited to, Port Ewen/Sleightsburg Pump Station, Abeel Street low pressure force main, and major city pump stations.

4.2 CONTAINMENT AND TREATMENT OF ODOROUS AIR EMISSIONS

Installation of covers and enclosures for wastewater and sludge treatment systems allows for the collection and treatment of odorous air emissions. Various treatment technologies are available, including wet scrubbers, activated carbon adsorbers, biofilters, thermal oxidizers, diffusion into activated sludge aeration tanks, and addition of odor counteractants and masking agents. Table 4-2 provides a brief summary of advantages, disadvantages, cost factors, and relative frequency of use of various technologies for treatment of odorous air emissions from municipal wastewater treatment facilities.

A. **Wet Scrubbers**. Wet scrubbers are an effective, well-demonstrated odor control technology. Two types of wet scrubbers are available: (1) packed tower; and (2) fine mist scrubbers. In both types, odorous air is contacted with a chemical solution containing sodium hypochlorite and caustic soda. This allows absorption and subsequent oxidation of the odorous compounds.

In a packed tower scrubber, the chemical solution is sprayed over a bed of plastic packing. The packing is used to promote intimate contact of the chemical solution with the odorous air. The chemical solution is continuously recirculated, with make-up chemicals added on a controlled basis to maintain the pH and oxidizing capability (ORP) of the solution. Spent chemical solution (with dilution water) is wasted from the system at a rate of 0.5 to 1.0 gpm per 1,000 cfm. The "cleaned" air is discharged through a demister.

Fine mist scrubbers use a reaction chamber without packing, typically constructed of fiberglass-reinforced plastic. Specially designed nozzles, in conjunction with air compressors, create a very fine mist of 10-micron droplets of the chemical solution to provide intimate contact with the odorous air, eliminating the need for packing. Such systems are designed without recirculation of the chemical solution, i.e., the solution only makes one pass through the chamber, after which it is collected and typically discharged back to the headworks. To prevent scaling and plugging of nozzles, make-up water passes through a water softener. Spent chemical solution is discharged at the rate of approximately 0.1 gpm per 1,000 cfm. Mist eliminators are often not used with fine mist scrubbers. In some cases, carryover of chemical mist to the outlet has been a problem.

Wet scrubbers typically reduce odors by 80 to 95 percent. Efficiency is dependent on the type of odor, inlet odor levels, and scrubber design and operation.

Packed bed scrubbers are considered an applicable technology for odor control at the Kingston WWTF. Based on the ranking and location of odor sources, two scrubbers are proposed: one to treat odorous air emissions from the plant headworks area (entrance chamber, grit tank, influent degritter enclosure, Head House bar screen room, and turbulent flow areas associated with the primary settling tanks); and one to treat odorous air emissions from the settled sewage wet well and from sludge treatment systems (gravity thickener, sludge degritter enclosure, dissolved air flotation thickener, and belt filter press).

B. **Activated Carbon Adsorbers**. Activated carbon absorbers can also be an effective means of odor and volatile organic compound (VOC) control. Their principal application is for low levels of odorous gases and VOCs, such as for dilute air streams or for polishing air discharges from wet scrubbers or other control devices.

Two types of carbon are in general use for odor and VOC control applications. For air streams containing H_2S, a caustic-impregnated carbon is often used. Where VOCs or non-H_2S odors are involved, virgin activated carbon is typically selected. The carbon must be periodically changed or regenerated due to saturation of the adsorption sites available on the carbon. For caustic-impregnated carbon, chemical regeneration can be accomplished using a potassium hydroxide or sodium hydroxide solution to desorb the H_2S, although replacement is more common and may be more economical. A recently introduced "catalytic" carbon for H_2S control promotes oxidation of H_2S to sulfate, allowing restoration of H_2S removal capacity by flushing with water. For virgin carbon, regeneration is conducted using thermal regeneration (furnace) or steam regeneration (in-situ). The full adsorption capacity of the carbon is usually not restored with regeneration. Carbon contaminated with VOCs, or the waste stream resulting from regeneration, may be considered a hazardous waste and subject to special disposal restrictions.

Carbon adsorbers may be expected to reduce odor detectability by 80 to 95 percent. However, removal efficiency may gradually decrease as the sites available for adsorption on the carbon are utilized.

Activated carbon adsorption is not considered to be a feasible alternative for odor control at the Kingston WWTF. For odor sources associated with the plant headworks, hydrogen sulfide concentrations are too high for consideration of activated carbon scrubbing. Frequent carbon regeneration and likely frequent carbon replacement are anticipated. For odor sources associated with sludge treatment systems, there are enough non-hydrogen sulfide compounds present that the carbon is expected to be exhausted fairly quickly. Packed tower chemical scrubbers are considered to be a better choice for odor control.

C. **Thermal Oxidation**. Thermal oxidation involves subjecting odorous air to sufficiently high temperatures to oxidize the odorous compounds. Several technologies are available to accomplish this, including direct flame incinerators, catalytic incinerators, recuperative oxidizers, and regenerative thermal oxidizers (RTOs). In addition, the capacity of an existing sludge or solid waste incinerator can sometimes be used as an odor control device. Of the thermal oxidation technologies currently being built for odor and VOC control, RTOs are the most efficient and economical.

RTOs destroy odors and VOCs by subjecting them to temperatures of 1500°F or greater. RTO systems reduce fuel consumption by preheating incoming air, and employ ceramic media to alternately capture and release the heat of combustion. Heat recovery is accomplished by cycling the direction of the incoming air so that it always passes through the hottest mass of ceramic media. High heat recovery efficiencies (90 to 95 percent) are possible using this approach.

For most municipal applications, capital and operating costs are high and RTO systems are not cost effective compared to other odor control alternatives. For this reason, thermal oxidation was eliminated from further consideration for odor control at the Kingston WWTF.

D. **Biofilters**. Biofilters remove odors through a combination of mechanisms such as adsorption, absorption, and biological oxidation. Odorous gas is passed upward through a bed of porous natural media such as compost, soil, peat, or other organic material at rates of 1 to 5 cfm per square foot. In most cases, a combination of materials is used that provides the required adsorptive capacity, ability to retain moisture, and porosity to maintain air flow.

Biofilters are economical to construct and operate. Some problems have been reported related to excessive drying of the media and short-circuiting of the odorous air stream. Recently, there has been a surge in use of biofilters for control of odors and VOCs, leading to more performance data and improved designs to overcome some of these reported problems of the first installations. It is difficult to predict the length of time that the biofilter media will efficiently remove odorous constituents before requiring replacement. Most biofilters in use today have a minimum media life of two years and an average life of five years before requiring replacement.

Proprietary biofilters packaged in containers are also available. These typically require the odorous air to be pre-heated to 60°F and its humidity controlled in a spray mist humidification chamber. An oil-fired boiler is typically used for the air heating system and must be housed in a building. The package biofilter is loaded at twice the rate as the "conventional" biofilter, and its smaller footprint would allow it and a boiler/blower building to be installed in the area north of the influent channel. The packaged biofilter media would also require replacement every five years.

Results of testing performed by Bowker & Associates indicate that the packaged biofilter system that is currently installed at the Kingston WWTF for control of odorous air emissions from the gravity thickener and dissolved air flotation thickener is relatively ineffective for odor control. The exhaust from the biofilter has been identified as a significant source of odors at the plant.

Test results indicate that odor concentrations are being reduced by only 30 percent by the biofilter.

Biofilters are not considered to be a feasible alternative for odor control at the Kingston WWTF due to site constraints and poor performance exhibited by the existing biofilter.

E. **Diffusion of Odors Into Activated Sludge Aeration Tanks**. Diffusion of odorous air emissions into activated sludge aeration tanks is another technology that has been successfully used to reduce odors at municipal wastewater treatment plants. This technology involves two steps: (1) the collection of odorous air emissions; and (2) introduction of the odorous air to the air supply system for activated sludge aeration tanks. For Kingston, this technology is not considered applicable since the aeration tanks have been identified as a significant source of odors at the treatment plant. Diffusion of odorous air into the activated sludge aeration tanks may only serve to increase the potential for odors from the aeration tanks.

F. **Odor Counteractants and Masking Agents.** Odor counteractants are formulations that reduce the intensity and/or detectability of odors by causing a physical or chemical reaction to occur with odorous compounds. Such formulations are proprietary and may consist of a blend of essential oils, organic acids, and other compounds. Limited data are available regarding their effectiveness, and few manufacturers have collected such data to support their claims of odor control. Odor counteractants may be dispersed into the air at the source of the odor, applied directly to the odorous material, sprayed into ductwork conveying odorous air, or atomized into a chamber designed to improve the contact between the odorous gas and the counteractant. The limited data that have been collected suggest a reduction in odor detectability of 20 to 40 percent.

Masking agents are merely perfumes that "cover up" an objectionable odor with a pleasant one. No reduction in odor detectability or intensity is achieved and, in fact, odor levels may actually increase. Masking agents may only be effective in changing the odor character near the source of the odor, as the pleasant odor of the masking agent may be "diluted out" as the odorous gas moves away from the odor source. Masking agents are ineffective for reducing complaints from neighboring residents.

Odor counteractants and masking agents are not considered to be feasible solutions for odor control at the Kingston WWTF.

4.3 OPERATIONAL OR DESIGN MODIFICATIONS

Plant performance relative to SPDES permit effluent limitations and performance requirements is excellent and is not a contributing factor to odor problems. The following paragraphs discuss operational or design modifications that were evaluated for odor control.

A. **Sludge Treatment And Disposal Alternatives**. Sewage sludge generated at the Kingston WWTF is hauled to the Ulster County Resource Recovery Agency's (UCRRA) solid waste transfer station in New Paltz for subsequent landfill disposal. Federal and state regulations governing the landfill disposal of municipal sewage sludge require treatment of the sludge by a "process to significantly reduce pathogens." In addition, the sludge must be dewatered to achieve a minimum solids concentration of 20 percent by weight. In conformance with these regulations, the Kingston WWTF provides treatment of sewage sludge consisting of:

- gravity thickening of primary sludge
- dissolved air flotation thickening of waste activated sludge
- anaerobic digestion of thickened primary and waste activated sludge
- belt filter press dewatering of digested sludge

Figure 4-1 illustrates the reduction in the volume and mass loading of sludge as it passes through the sludge treatment system. Because sludge treatment systems have been identified as significant sources of odors at the Kingston WWTF, alternatives involving elimination of these sources were explored. Specifically, options involving the contractual hauling of liquid sludge for off-site treatment were explored. Westchester County currently has a contract from hauling and disposal of liquid sludge from the Ossining wastewater treatment plant. Liquid sludge is hauled in 7,000-gallon tanker trucks from the facility for off-site treatment and disposal. The current rate for sludge hauling and disposal is approximately $0.09 per gallon. The rate of $0.09 per gallon was assumed for use in this analysis. Actual cost is dependent on hauling distance and disposal location.

Table 4-3 summarizes estimated annual sludge disposal costs for dewatered and liquid sludge disposal. As shown in Table 4-3, the City of Kingston disposed of 2,839 wet tons of dewatered sludge over the 1-year period of September 2001 through August 2002. At the current tipping fee of $75 per wet ton, the annual cost of sludge disposal was approximately $213,000.

If belt filter press dewatering were eliminated at the Kingston WWTF, sludge disposal costs would increase by more than 55 percent to approximately $332,000 per year. Approximately two 7,000-gallon tanker trucks per day would be required on average based on continuous sludge removal (365 days per year). If anaerobic sludge digestion were eliminated, annual sludge disposal costs would increase by nearly 110 percent to approximately $446,000 per year. Finally, if sludge thickening were eliminated, annual sludge disposal costs would increase by more than ten-fold to approximately $2.9 million per year.

Unless a major upgrade of existing sludge treatment facilities is necessary for other reasons, alternative sludge treatment and disposal options do not appear cost effective.

B. **Reduction In Sludge Blanket Levels.** Based on discussions with the plant operator, under normal operating conditions, sludge blanket levels in primary and secondary settling tanks are maintained at minimum levels. When emergency maintenance and/or repairs to the sludge collector drive mechanism installed in the gravity thickener are necessary, the operators are forced to increase sludge blanket levels in the primary settling tanks due to the lack of backup facilities for primary sludge thickening. When this occurs, odor complaints reportedly increase.

Because the thickener drive has been in service for more than 30 years, the frequency of emergency maintenance and repairs is increasing. In a separate report being prepared by Brinnier & Larrios to address wastewater treatment capacity issues at the Kingston WWTF, it will be recommended that the City replace the thickener drive to improve mechanical reliability. This, in turn, should help to reduce potential for odor complaints at the plant.

C. **Modifications to Handling and Storage of Residuals.** Residuals generated at the Kingston WWTF include wastewater screenings, grit (from influent and primary sludge degritting), floatable solids (skimmings) removed from the surface of primary and secondary settling tanks, and sewage sludge. All residuals are hauled by truck to the UCRRA transfer station in New Paltz for subsequent landfill disposal.

Grit removed from the influent wastewater and primary sludge is continuously discharged to dump trucks for subsequent hauling to the UCRRA transfer station. Wastewater screenings and skimmings from the primary settling tanks are added to trucks before they are hauled to the transfer station. The trucks are located outdoors, providing a potential source of odors while the trucks are being filled. The magnitude of these sources of odors, however, is considered small in comparison to the other sources identified. After odor control measures are implemented for the major odor sources identified, the City may want to consider enclosing the truck loading operations for additional odor control.

The current dimensions of the garage prevent the overhead door from being closed when a sludge truck is parked for loading. This creates a potential source of odors while the truck is being filled. To eliminate this potential source of odors, the City may want to consider loading sludge to a container that would allow the overhead door to be closed.

CHAPTER 5

RECOMMENDED PLAN

5.1 DESCRIPTION OF ODOR CONTROL RECOMMENDATIONS

The recommended plan to reduce odors generated at the Kingston WWTF consists of two components that can be implemented sequentially. The first component, which can be implemented quickly (before summer of 2003) by the City, involves the installation of bulk chemical storage and feed facilities at the site of the former City incinerator for chemical addition upstream of the Rondout interceptor sewer inverted siphon.

It is our understanding that building space exists for the installation of a bulk chemical storage tank, chemical metering pumps and associated spill containment provisions. It is recommended that the chemical storage and feed facilities be designed to provide flexibility for use of liquid sodium hypochlorite and iron salt solutions (ferrous chloride, ferrous sulfate, or ferric chloride).

Sodium hypochlorite is the recommended chemical feed alternative due to its ability to reduce odors associated with both hydrogen sulfide and other reduced sulfur compounds. Iron salt solutions, in comparison, do not react with reduced sulfur compounds that can contribute to odors. In addition, iron salt solutions also result in the generation of chemical solids. These solids may accumulate in the Rondout interceptor sewer inverted siphon when flow conditions result in low flow velocities.

Specific recommendations for the chemical storage and feed facilities are summarized as follows:

1. A 6,000-gallon fiberglass chemical storage tank with synthetic veil suitable for storage of 15 percent sodium hypochlorite (bleach) solution, liquid ferrous chloride (18 to 28 percent solution), or liquid ferrous sulfate (13.6 to 16.3 percent solution).

2. A 4,000-gallon tanker truck unloading station with spill containment designed in conformance with New York State chemical bulk storage regulations.

3. Two liquid chemical metering pumps with associated piping, instrumentation, and controls for delivery of chemicals to the trunk sewer upstream of the Rondout interceptor sewer inverted siphon.

The second component of the recommended plan for reducing odors at the Kingston WWTF involves the design and construction of two odor control units at the facility site. One unit will be designed to treat odorous air emissions associated with the plant headworks area (i.e., entrance chamber, grit tank, influent degritter enclosure, Head House bar screen room, and areas of turbulent flow at the primary settling tanks, including the influent flow distribution channel, effluent weir trough area, and effluent collection channel), and the other will be designed to treat odorous air emissions from the settled sewage wet well and from sludge treatment systems (sludge degritter enclosure, gravity thickener, dissolved air flotation thickener, and belt filter press).

Figure 5-1 illustrates the proposed location for each of the odor control units on the facility site. Proposed ventilation rates for the areas to be served by each of the odor control units are summarized in Table 5-1.

5.2 PROJECT COST ESTIMATES

Project cost estimates have been prepared for each component of the odor control recommendations and are summarized in Tables 5-2 and 5-3. As shown in Table 5-2, the total project cost for a chemical storage and feed system for chemical addition to the Rondout interceptor sewer inverted siphon is estimated at $390,000. The total project cost for design and construction of odor control units at the Kingston WWTF is estimated at $2,200,000, as shown in Table 5-3. Estimates for annual O&M costs for the recommended improvements are summarized in Table 5-4 and are estimated to total approximately $130,000 per year.

TABLES

TABLE 2-1

PLANT INFLUENT MONITORING DATA
Odor Reduction Analysis and Study
Wastewater Treatment Facility, Kingston, NY

MONTH	SEWAGE FLOW			DAILY AVERAGE $CBOD_5$		DAILY AVERAGE TSS	
	DAILY AVERAGE (MGD)	PEAK DAY (MGD)	INSTANTANEOUS PEAK (MGD)	CONC. (MG/L)	LOAD (LB/DAY)	CONC. (MG/L)	LOAD (LB/DAY)
September 01	3.89	6.29	11.9	143	4,643	130	4,221
October 01	3.80	4.67	11.9	160	5,064	158	5,001
November 01	3.86	4.65	9.8	189	6,080	164	5,275
December 01	3.83	5.96	11.4	167	5,337	140	4,474
January 02	3.61	4.21	8.4	167	5,021	138	4,149
February 02	4.14	5.36	11.9	153	5,280	138	4,763
March 02	4.66	6.89	12.1	137	5,324	140	5,441
April 02	4.32	5.79	11.9	136	4,904	104	3,750
May 02	4.82	8.87	11.8	127	5,109	119	4,788
June 02	4.44	7.70	11.9	157	5,810	190	7,031
July 02	3.43	4.60	11.5	165	4,713	159	4,542
August 02	3.28	4.89	12.0	178	4,863	150	4,098
Average	4.01	-	-	155	5,179	144	4,794
Maximum	4.82	8.87	12.1	189	6,080	190	7,031
Minimum	3.28	-	-	127	4,643	104	3,750

TABLE 2-2

DEWATERED SLUDGE DA TA
Odor Reduction Analysis and Study
Wastewater Treatment Facility, Kingston, NY

MONTH	SLUDGE REMOVED			
	WET WEIGHT (TONS)	PERCENT SOLIDS	DRY WEIGHT (TONS)	DRY TON PER MGAL
September 01	248	19.4	48.1	0.41
October 01	210	18.9	39.7	0.34
November 01	257	19.4	49.9	0.42
December 01	274	18.8	51.5	0.43
January 02	340	20.6	70.0	0.63
February 02	210	20.2	42.4	0.37
March 02	202	21.2	42.8	0.30
April 02	253	20.7	52.4	0.40
May 02	267	23.4	62.5	0.42
June 02	205	22.6	46.3	0.35
July 02	202	21.5	43.4	0.41
August 02	171	20.5	35.1	0.35
Annual Total	2,839		584.1	
Average Month	237	20.6	48.7	
Maximum Month	340	20.6	70.0	
Minimum Month	171	20.5	35.1	

TABLE 3-1

RESULTS OF ODOR DISPERSION MODELING
Odor Reduction Analysis and Study
Wastewater Treatment Facility, Kingston, NY

SOURCE	ODOR CONCENTRATION, D/T	AIR FLOW, CFM	1-HOUR AVERAGE ODOR CONCENTRATION AT 100 FEET (30 M)
1. Primary effluent pump station	3,600	680	44
2. First bar rack room	5,300	864	31
3. Second bar rack room	4,300	380	29
4. BFP room	1,400	2,400	19
5. Aeration tanks	1,600	3,500	17
6. Primary clarifiers – turbulent	4,800	60	11
7. Biofilter	5,300	300	11
8. Primary clarifiers – quiescent	1,200	762	9
9. Grit chamber	4,300	55	7
10. Degritter building	1,400	1,270	7

TABLE 4-1

SUMMARY OF CHEMICAL CONTROL ALTERNATIVES
Odor Reduction Analysis and Study
Wastewater Treatment Facility, Kingston, NY

CHEMICAL	RELATIVE USAGE	ADVANTAGES	DISADVANTAGES
OXIDATION			
Hydrogen peroxide	Widely used	Effective for odor/sulfide control in gravity sewers or force mains; simple installation.	Costs can be high if dosages much greater than stoichiometric amount for sulfide oxidation. Does not prevent downstream odor formation. Potential for formation of chlorinated byproducts.
Sodium hypochlorite	Widely used	Applicable to gravity sewers or force mains. Chlorine residual prevents downstream odor formation. Minimizes potential for corrosion in pipes.	Safety considerations.
Potassium permanganate	Moderate usage	Effective, powerful oxidant.	High cost, difficult to handle.
Sodium permanganate	Low usage (new)	Effective, powerful oxidant; feed equipment simplified.	High chemical cost.
PRECIPITATION			
Iron salts	Widely used	Economical for sulfide control in gravity sewers or force mains.	Does not control non-H_2S odors; sulfide control to low level may be difficult; increased sludge production.
OXYGEN ADDITIVES			
Calcium nitrate (Bioxide)	Moderate usage	Performs best when added to long force mains or low velocity gravity sewers with detention times longer than 12 hours.	High chemical cost.

TABLE 4-2

SUMMARY OF ODOROUS AIR TREATMENT ALTERNATIVES
Odor Reduction Analysis and Study
Wastewater Treatment Facility, Kingston, NY

TECHNIQUE	FREQUENCY OF USE	COST FACTORS	ADVANTAGES	DISADVANTAGES
Packed tower wet scrubbers	High	Moderate capital and O&M cost	Effective and reliable; long track record	Spent chemical must be disposed; high chemical consumption
Fine mist wet scrubbers	Medium	Higher capital cost than packed towers	Lower chemical consumption; can be designed for VOC removal	Water softening required for scrubber water; larger scrubber vessel
Activated carbon adsorbers	High	Cost-effectiveness depends on frequency of carbon replacement/regeneration	Simple; few moving parts; effective	Only applicable for relatively dilute air streams in order to ensure long carbon life.
Biofilters	High	Low capital and O&M costs	Simple; minimal O&M	Large land requirement; design criteria developing
Thermal oxidizers	Low	Very high capital and O&M (energy) costs	Effective for odors and VOCs	Only economical for high-strength, difficult to treat air streams
Diffusion into activated sludge basins	Low	Economical if use existing blowers/diffusers	Simple; low O&M; effective	Concern for blower corrosion; may not be appropriate for very strong odors
Odor counteractants	High	Cost dependent on chemical usage	Low capital cost	Limited odor removal efficiency (less than 40 percent)

TABLE 4-3

ESTIMATED ANNUAL SLUDGE DISPOSAL COST
Odor Reduction Analysis and Study
Wastewater Treatment Facility, Kingston, NY

	ANNUAL COST ($ PER YEAR)	BASIS
Current practice (dewatered sludge)	$ 212,925	2,839 wet tons @ $75/ton
Sludge Disposal Alternatives:		
Raw primary and waste activated sludge	$2,943,000	32.7 MGal @ $0.09 per gallon
Thickened sludge	446,400	4.96 MGal @ $0.09 per gallon
Digested sludge	332,100	3.69 MGal @ $0.09 per gallon

TABLE 5-1

PRELIMINARY SIZING FOR ODOR CONTROL UNITS
Odor Reduction Analysis and Study
Kingston Wastewater Treatment Facility
City of Kingston, New York

	Ventilation Rate, cfm	**Basis**
Odor Control Unit No. 1		
Entrance Chamber	800	20 ACPH (exhauster capacity)
Grit Tank	200	120 FPM
Influent Degritter Room	500	20 ACPH
Head House (Bar Screen Room)	400	12 ACPH
Primary Settling Tanks (Turbulent Areas)	500	120 FPM
Total (Odor Control Unit No. 1) =	2,400	
Odor Control Unit No. 2		
Settled Sewage Wet Well	300	120 FPM
Gravity Thickener and DAF Thickener	300	Ventilation rate to biofilter
Sludge Degritter Room	600	12 ACPH
Belt Filter Press Enclosure	2,200	30 ACPH (intermittent)
Total (Odor Control Unit No. 2) =	3,400	

TABLE 5-2

PROJECT COST ESTIMATE
CHEMICAL STORAGE AND FEED FACILITIES FOR ODOR CONTROL
Kingston Wastewater Treatment Facility, City of Kingston, New York

		Estimated Cost
Construction Costs		
Fiberglass chemical storage tank [1]	$	52,000
Spill containment area for bulk storage tank	$	26,000
Chemical metering pumps	$	39,000
Chemical piping, valves, fittings, etc.	$	52,000
Electrical work, instrumentation and controls	$	58,500
Truck unloading station (with spill containment)	$	32,500
Subtotal =	$	260,000
Allowance for contingencies	$	52,000
Total Construction Cost =	$	312,000
Allowance for fiscal, legal, administrative and engineering fees	$	78,000
Total Project Cost =	$	390,000

TABLE 5-3

PROJECT COST ESTIMATE
ODOR CONTROL MODIFICATIONS
Kingston Wastewater Treatment Facility, City of Kingston, New York

		Estimated Cost
Construction Costs		
Contractor mobilization, bonds, insurance and general conditions	$	100,000
Odor Control System No. 1 [1]		
Packed bed scrubber system [2]	$	220,000
Aluminum covers	$	40,000
Building enclosure	$	70,000
Ductwork, supports and accessories	$	55,000
Odor Control System No. 2 [3,4]		
Demolition (lime storage silo and biofilter)	$	100,000
Packed bed scrubber system	$	230,000
Aluminum covers	$	70,000
Belt filter press enclosure	$	80,000
Building enclosure	$	75,000
Ductwork, supports and accessories	$	60,000
Miscellaneous (sitework, instrumentation, etc.)	$	100,000
Electrical	$	180,000
Subtotal =	$	1,380,000
Allowance for contingencies	$	320,000
Total Construction Cost =	$	1,700,000
Allowance for fiscal, legal, administrative and engineering costs	$	500,000
Total Project Cost =	$	2,200,000

Notes:

(1) Odor control for Entrance Chamber, grit tank, influent degritter enclosure, Head House bar screen room and turbulent flow areas associated with primary settling tanks.

(2) Includes scrubber vessel, exhaust fan, chemical storage tank, recirculation pumps, plumbing, valves, chemical feed pumps, pH and ORP probes, and control panel.

(3) Odor control for settled sewage wet well, primary sludge degritter enclosure, gravity thickener, dissolved air flotation thickener, and belt filter press enclosure.

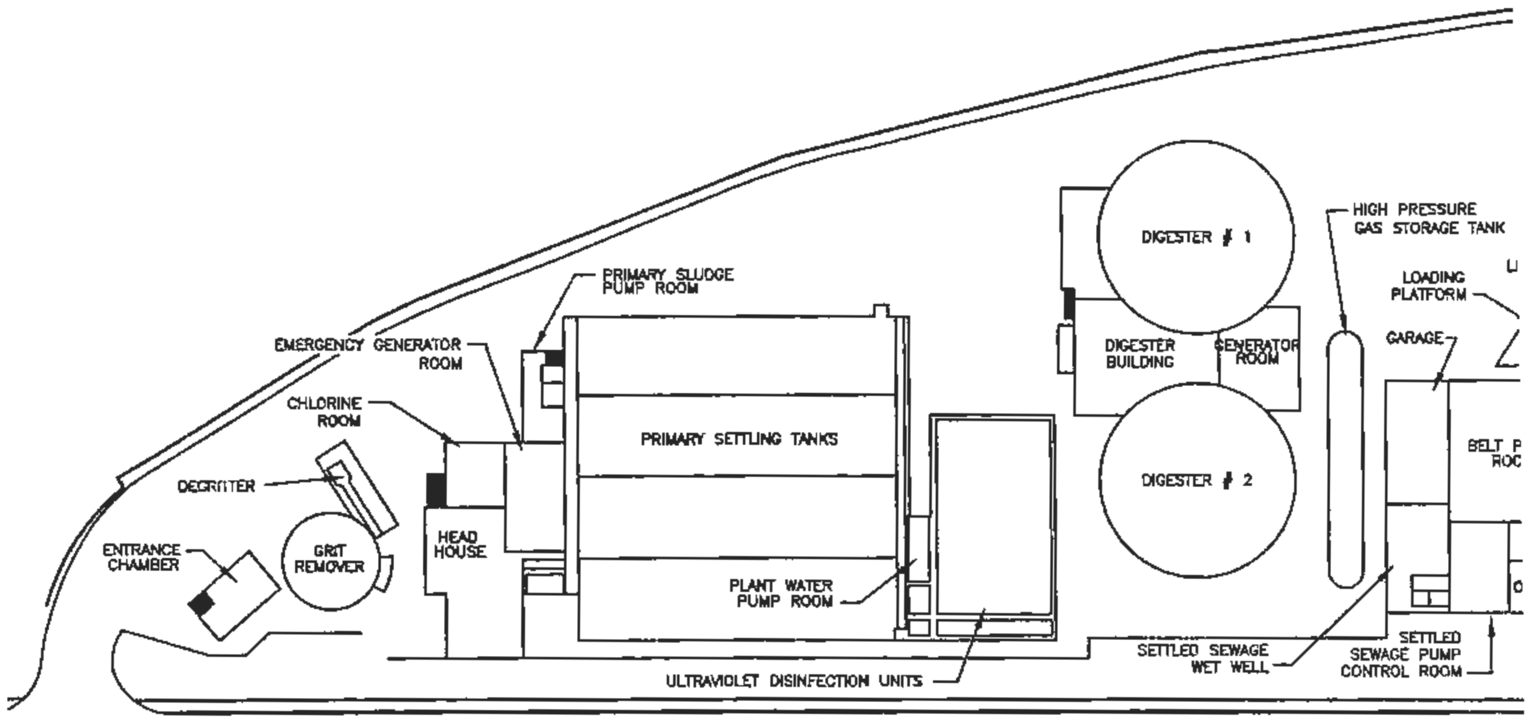
(4) See report by Brinnier & Larios for cost associated with replacement of sludge collector drive mechanism for gravity thickener.

TABLE 5-4

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COSTS
Odor Reduction Analysis and Study
Wastewater Treatment Facility, Kingston, NY

	ANNUAL COST ($ PER YEAR)
Chemical Storage and Feed System - Rondout Interceptor	
Labor	$ 6,500
Chemicals	20,000
Electric	1,500
Equipment, materials, and supplies	20,000
Subtotal (Chemical Storage and Feed System)	**$48,000**
Odor Control Unit No. 1 - Kingston WWTF	
Labor	$ 6,500
Chemicals	9,500
Electric	5,500
Equipment, materials, and supplies	18,000
Suhtotal (Odor Control Unit No. 1)	**$39,500**
Odor Control Unit No. 2 - Kingston WWTF	
Labor	$ 6,500
Chemicals	10,000
Electric	6,500
Equipment, materials, and supplies	18,000
Subtotal (Odor Control Unit No. 2)	**$41,500**
TOTAL ANNUAL O&M COST	**$129,000**

FIGURES



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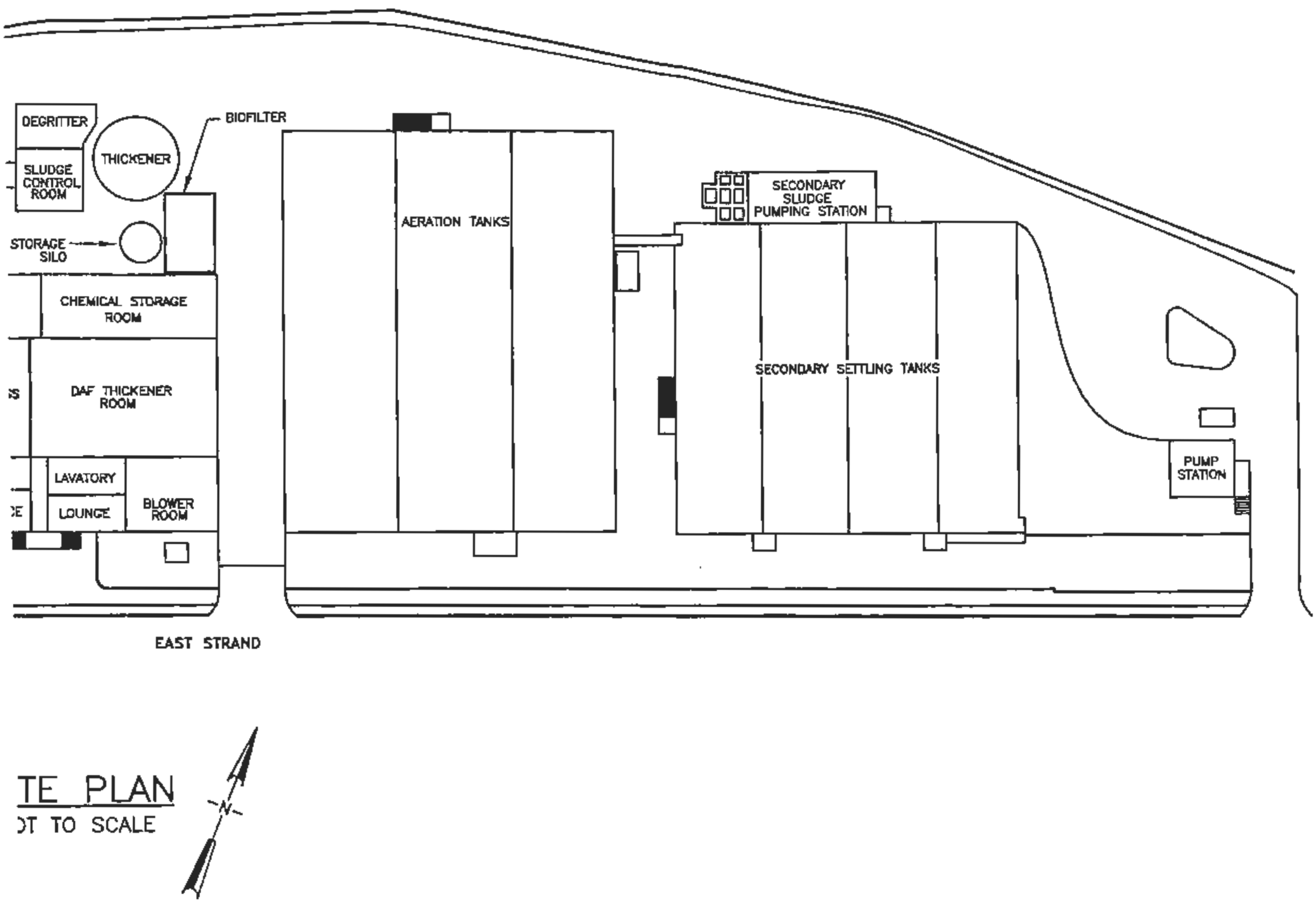


Stearns & Wheler, LLC
Environmental Engineers and Scientists

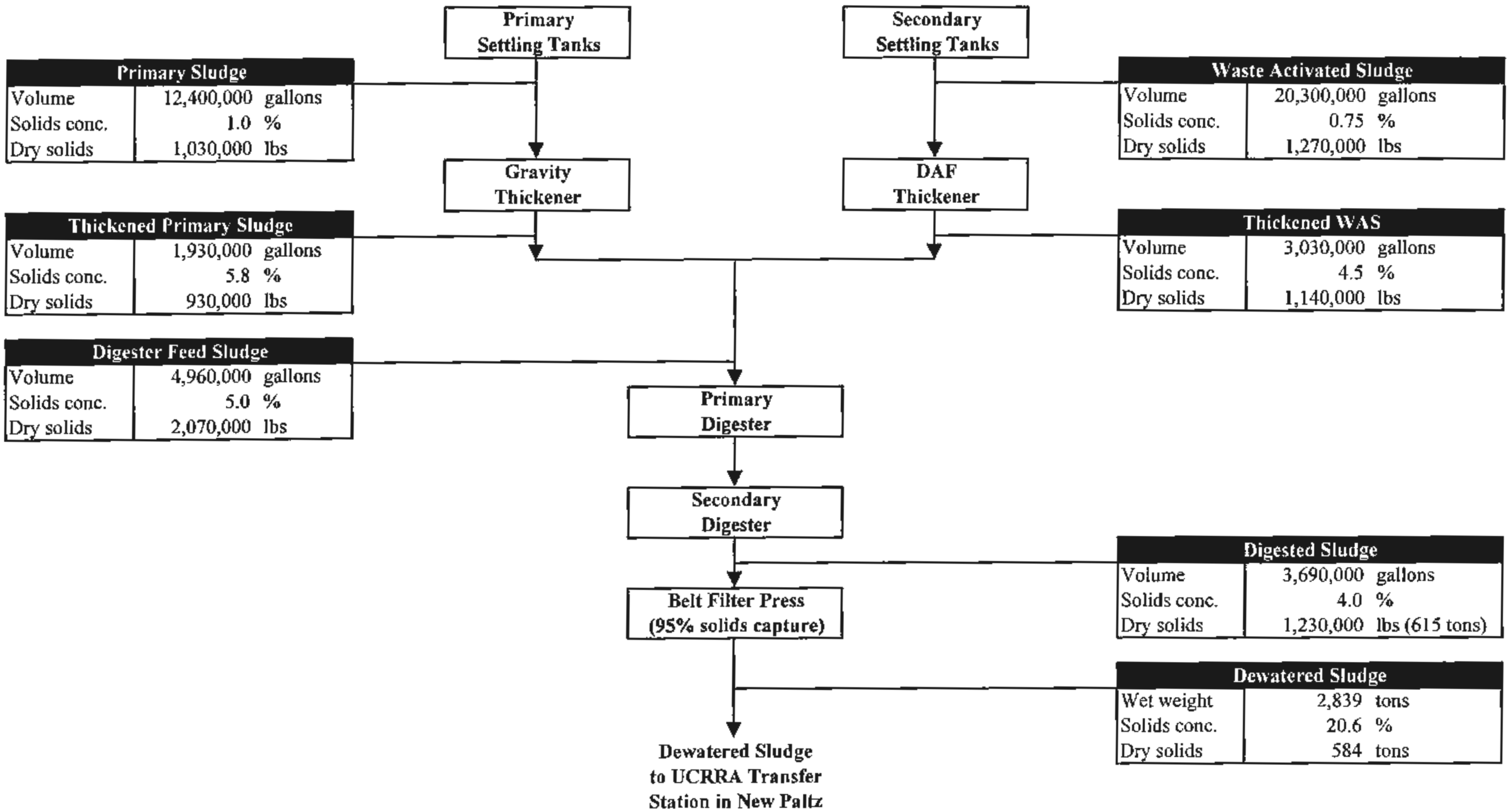
CITY OF KINGSTON, NEW YORK
KINGSTON WASTEWATER TREATMENT FACILITY

DATE:1/03 JOB No.:20224

FIGURE 2–1
SITE PLAN

FIGURE 4-1

ANNUAL SLUDGE PRODUCTION AND TREATMENT
Odor Reduction Analysis and Study
Kingston Wastewater Treatment Facility
City of Kingston, New York



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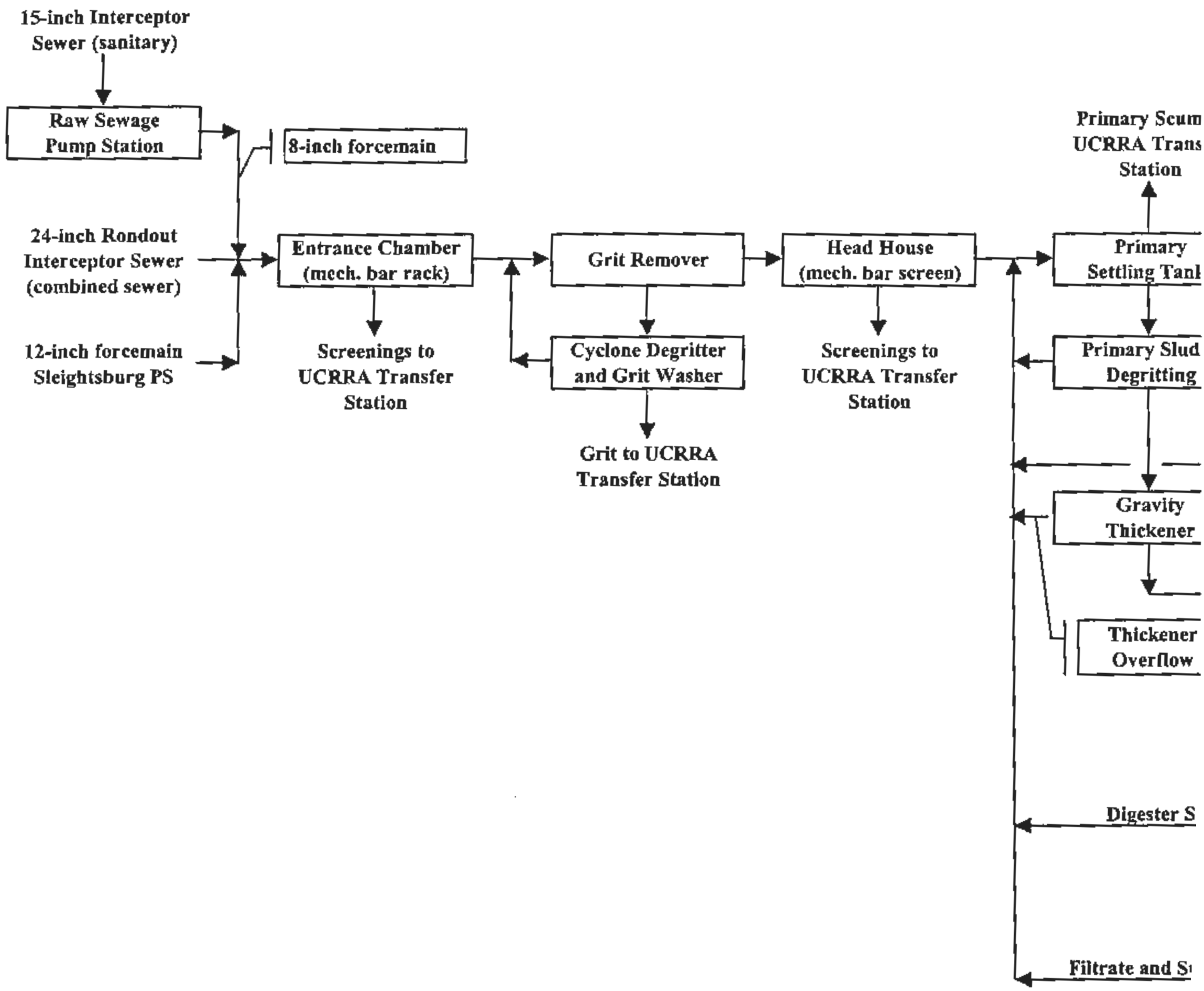

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TREATMENT FACILITY
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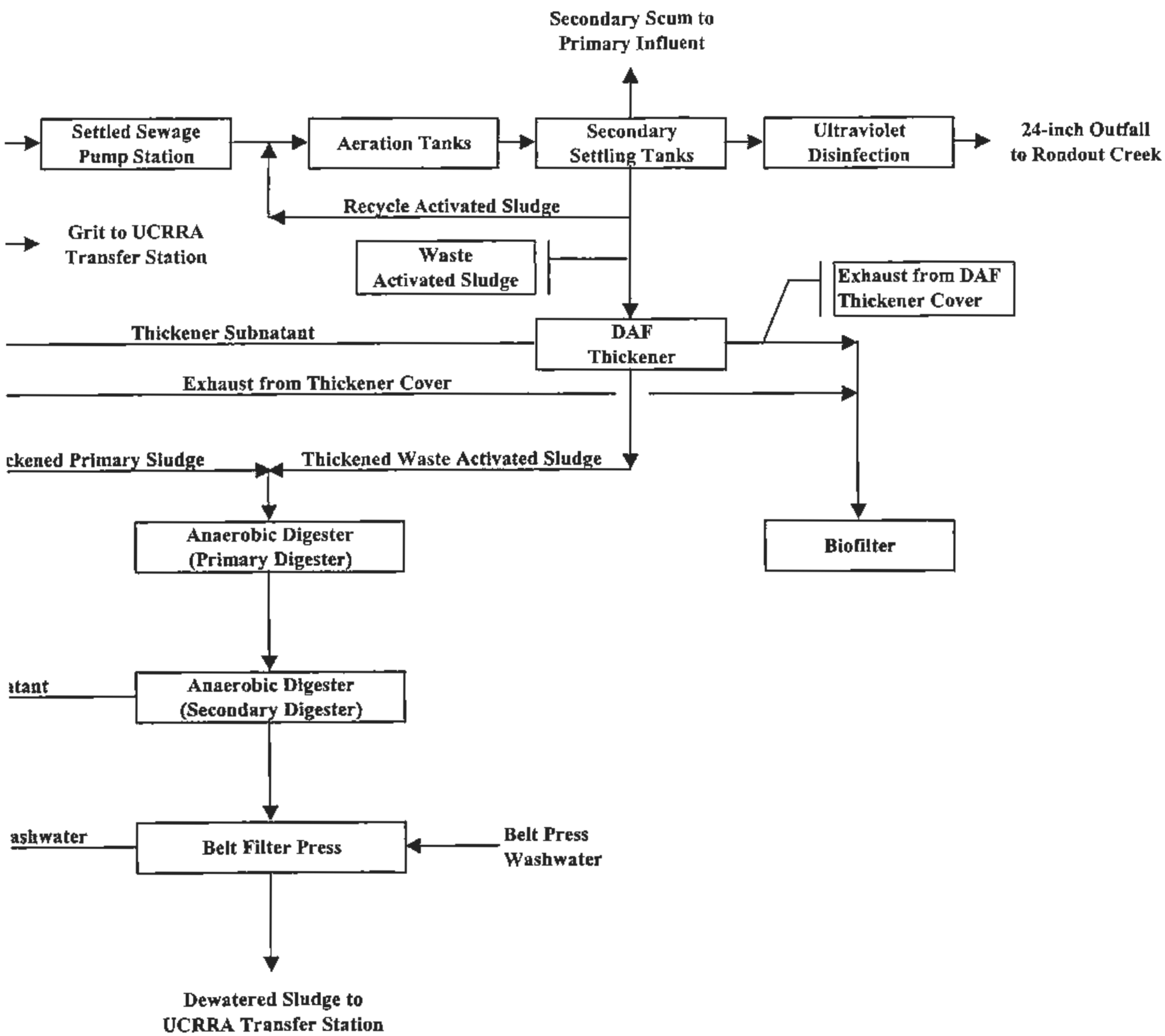
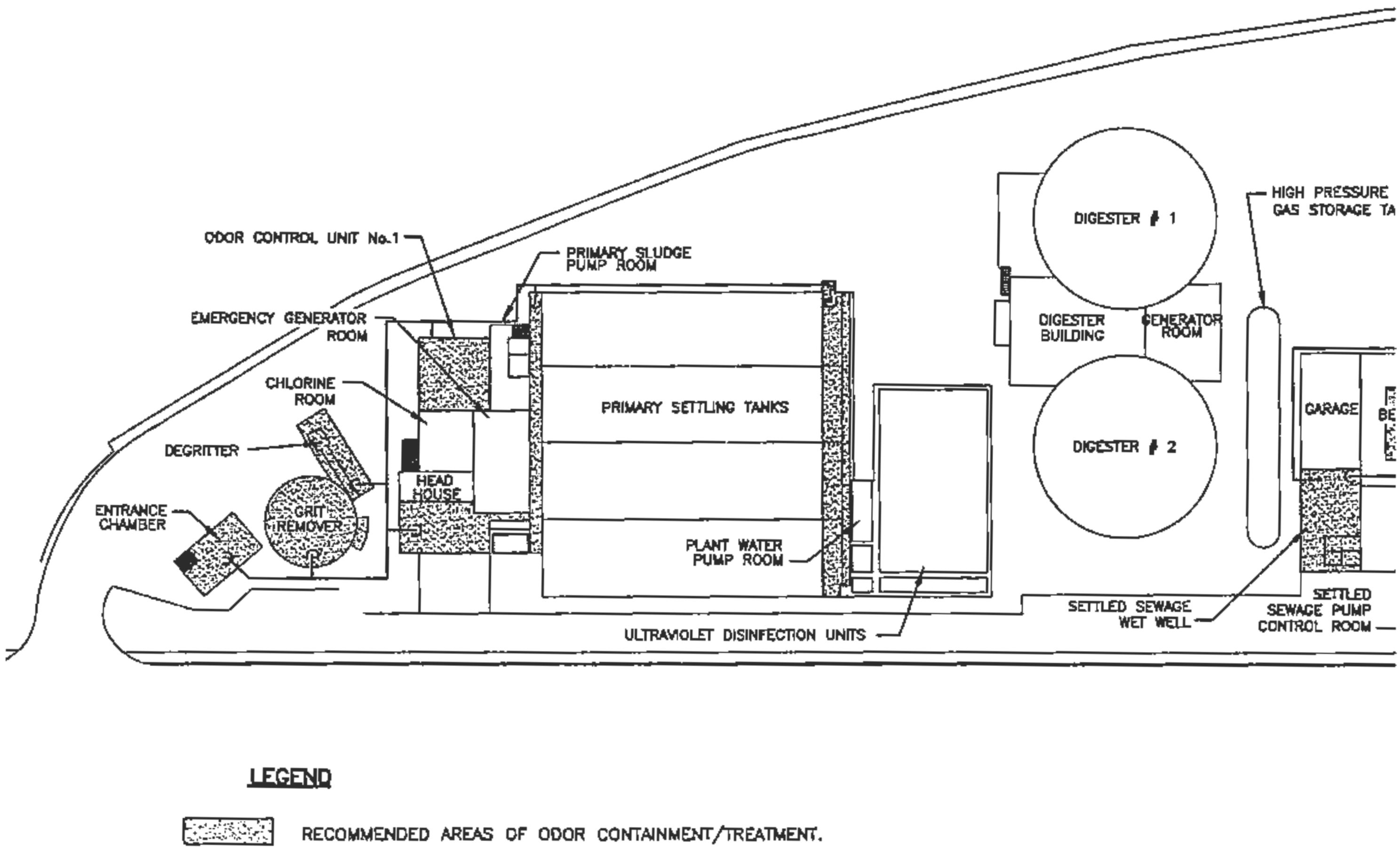
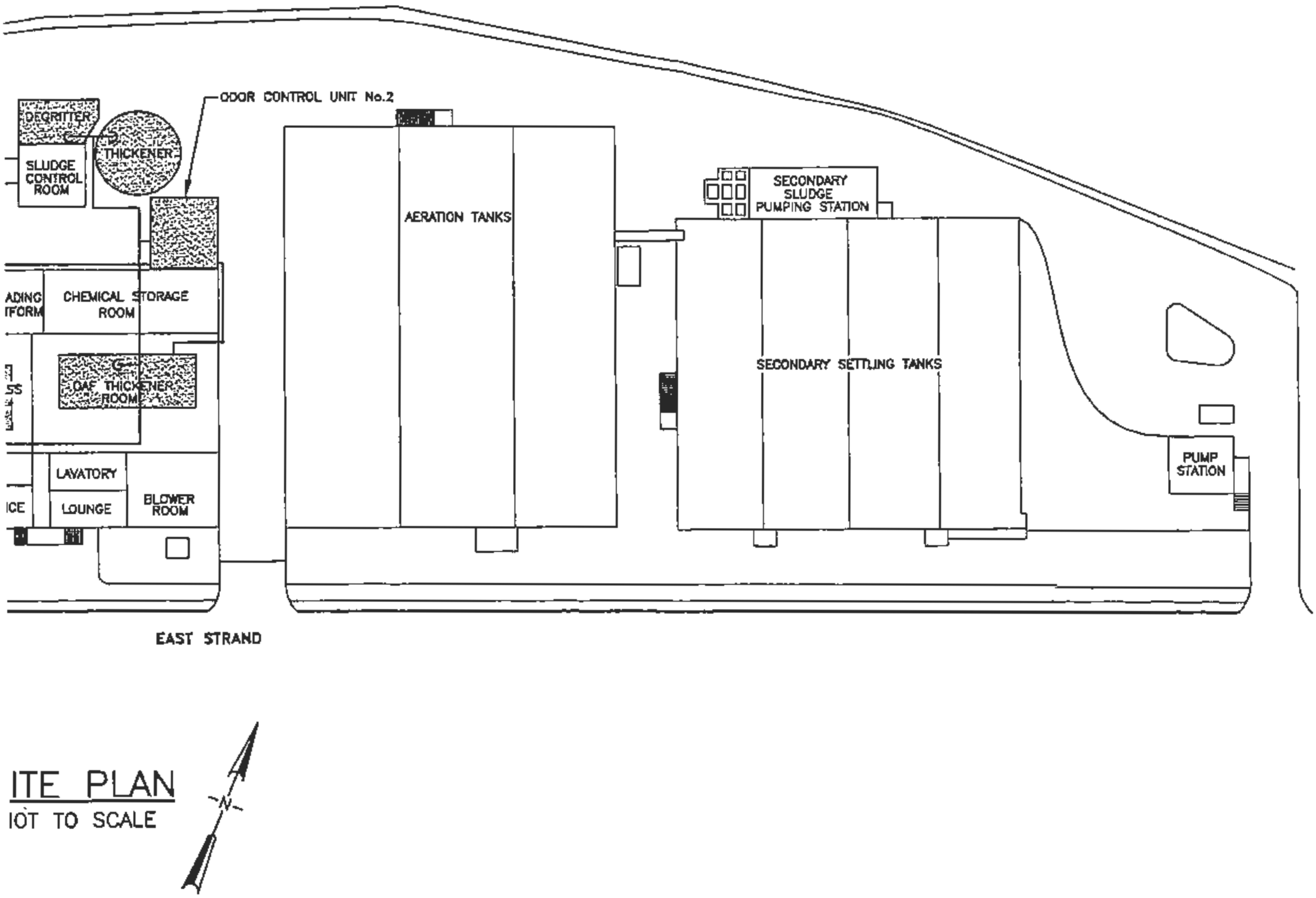




1/03 CAZ HCC
M:\20224\FIGURE\20224F01.DWG



ITE PLAN
IOT TO SCALE

Stearns & Wheler, LLC Environmental Engineers and Scientists	CITY OF KINGSTON, NEW YORK KINGSTON WASTEWATER TREATMENT FACILITY
DATE:1/03 JOB No.:20224	FIGURE 5–1 PROPOSED ODOR CONTROL MODIFICATIONS

APPENDICES

APPENDIX A

AIR EMISSIONS SAMPLING PROGRAM

APPENDIX A

AIR EMISSIONS SAMPLING PROGRAM

Samples of air emissions from known and suspected sources of odors were collected using typical industry standards for odor panel and reduced sulfur analysis. A sample of odorous air was drawn from the odor source through teflon tubing into a 10-liter Tedlar sample bag using a vacuum chamber and air sampling pump. This allowed the sample air to flow directly into the bag without potential contamination by the pump. The Tedlar bag was first filled and then purged to "condition" the bag so as to minimize odor adsorption.

For sources such as stacks or vents where the air flow was known or could be measured, a representative sample was withdrawn from the duct or pipe through the sampling tubing and into the Tedlar sample bag. For area sources such as the aeration basins, a floating flux chamber was used to isolate a known surface area. Odor-free, "ultra zero" air was introduced into the flux chamber at 5.0 liter per minute in accordance with USEPA recommended practice. After approximately 10 minutes, air was withdrawn from the flux chamber at a rate of 3.0 liters per minute into the Tedlar sample bag. The bag was filled, purged, and refilled with sample air. A diagram of the flux chamber sampling train is shown in Figure A-1.

In addition to collecting odorous gas samples for odor panel analyses, hydrogen sulfide (H_2S) levels were directly measured at the same point that the gas samples were collected. Atmospheric H_2S was measured using a Jerome 631X gold film H_2S analyzer (0 to 100 ppm range). To document diurnal fluctuations in atmospheric H_2S levels, an App-Tek OdaLog H_2S analyzer/datalogger was installed above the influent channel in the first bar rack room. The analyzer was programmed to measure H_2S levels every five minutes and store the collected data. The instrument records to the nearest 1 ppm.

Air samples were shipped via overnight carrier to St. Croix Sensory in Stillwater, MN for odor panel testing, and to Performance Analytical in Simi Valley, CA for reduced sulfur analyses.

ANALYTICAL PROCEDURES

A. **Odor Concentration.** Air samples were analyzed for odor concentration by St. Croix Sensory using a forced choice dynamic triangle olfactometer according to the ASTM Standard E-679 standard. This test determines the number of times that an air sample must by diluted with clean air before odor is no longer detectable by 50 percent of the odor panel. The dilution is known as the dilutions-to-threshold (D/T) ratio.

The olfactometer presents six different dilutions of the odorous sample for evaluation by a panelist. The panelist is presented with three air flows for each dilution. Two of the air flows are clean air "blanks" and the third is the diluted odorous sample. The air streams are emitted from identical sniffing ports at a rate of 20 liters per minute. Clean air is provided by stainless steel oil-less air compressor, and is filtered with activated carbon.

The panelist is required to determine which sniffing port contains the odorous air. The simultaneous presentation of two blanks along with the odor helps to eliminate "false positives" which could occur if only the odor were presented. The statistical nature of the test requires the panelist to make a selection, even if they are unsure of their answer. The individual panelist registers his/her selection by pressing a button corresponding to the sniffing port which they think contains the odor. After making their selection, the panelist proceeds to the next lower dilution level.

All six dilutions are evaluated by each panelist. Panelists are not given any indication as to "right" or "wrong" answers. This is to eliminate any bias which may influence the panelists' answers. The sniffing ports that emit the odor are changed in a random fashion between odor samples. This prevents a panelist from memorizing which port has the odor. Further, the panelist is not given any information as to the source of the odorous sample.

After the panel has completed a sample, the machine is purged with clean air. The next odorous air sample is connected and allowed to equilibrate before testing resumes.

B. **Reduced Sulfur Analysis**. Split samples of selected odorous air streams were sent to a separate laboratory for quantification of reduced sulfur compounds that are the principal odorants at wastewater treatment plants. Liquid stream processes, such as the aerated grit chamber and primary clarifiers, typically release hydrogen sulfide as the principal odorant. However, sludge handling processes often emit a complex mixture of reduced sulfur compounds that includes methyl mercaptan, dimethyl sulfide, and others.

Reduced sulfur compounds were analyzed by Performance Analytical in Simi Valley, CA using a gas chromatograph-sulfur chemiluminescence detector in accordance with ASTM Standard D 5504-1.

C. **Liquid Analysis.** Bowker & Associates conducted sampling of wastewater three times on October 1, 2002 and twice on October 2, 2002. On-site measurements were made of dissolved sulfide, pH, oxidation-reduction potential (ORP), and temperature. Dissolved sulfide was estimated using Sensidyne color detector tubes. pH, ORP, and temperature were measured using a Myron L Model 3P portable instrument calibrated on September 30.

RESULTS

A. **Air Samples from Liquid Treatment Process.** Table A-1 summarizes the odor concentration, field H_2S, and reduced sulfur data collected from the October 1-2, 2002 sampling program. Results are discussed below by source, beginning at the first bar rack room.

Air samples collected from the first bar rack room located in tbe entrance chamber showed relatively high odor concentrations of 5,300 D/T and 3,200 D/T on the first and second days of sampling, respectively (Samples 6 and 16). Field H_2S was 6 ppm and 4 ppm on those two days. Tbe ventilation fan was not operational at the time of sampling.

A datalogging H_2S analyzer (OdaLog) was installed in the bar screen channel (below the grating) in the entrance chamber for approximately 29 hours. Figure A-2 displays the results. Peak H_2S levels of up to 100 ppm were recorded during evening and early morning bours. The average H_2S concentration was 20 ppm. This plot clearly shows that peak H_2S concentrations were significantly higher than levels measured at the time of sampling. Further, as expected, there is a significant diurnal fluctuation in H_2S concentrations.

Air samples collected from the surface of the grit tank showed similar odor concentrations of 4,300 and 2,100 D/T on the first and second days of sampling, respectively (Samples 1 and 12). Field H_2S was 2.0 ppm on tbe first day, but only 0.1 ppm on the second day.

The degritter room exhaust (Sample 13) showed a moderate odor concentration of 1,400 D/T. Laboratory measurement of reduced sulfur compounds showed H_2S at 275 ppb (approximately 0.3 ppm).

Sample 7 from the second bar rack room located in the Head House was collected 10 minutes after Sample 6 from the first bar rack room and showed very similar results. Odor concentration was 4,300 D/T and field H_2S was 5.0 ppm. The ventilation fan in this room was not operational at the time of sampling.

The quiescent portion of the primary clarifiers showed moderate odor concentrations of 1,200 D/T on the first day and 1,000 D/T on the second day (Samples 2 and 14). Field H_2S was 0.08 and 0.3 ppm, respectively.

Due to turbulence and stripping of H_2S and other odorants, the primary clarifier effluent channel had significantly higher odor and H_2S emissions than the quiescent surface. Odor concentrations were 4,800 D/T and 3,500 D/T on the first and second days, with corresponding field H_2S levels of 4.5 and 6.0 ppm (Samples 3 and 15). Laboratory analyses for reduced sulfur compounds showed even higher H_2S concentration of 8.750 ppb (8.75 ppm), with 556 ppb of methyl mercaptan and 70 ppb of dimethyl sulfide. The two latter compounds have a "rotten cabbage" or "rotten vegetable" odor character.

A sample from the primary effluent pump station wet well (Sample 10) showed a relatively high odor concentration of 4,600 D/T, with a field H_2S of 1.7 ppm.

One sample was collected from the aeration tank surface. Odor concentration was surprisingly high at 1,600 D/T (Sample 5). Although odor emissions from aeration tanks vary depending on wastewater characteristics, operating mode (complete mix, plug flow), type of aeration device, MLSS concentration, and other factors, odor concentrations are typically in the 100 to 500 D/T range. Hydrogen sulfide concentration, at 0.025 ppm or 25 ppb, is somewhat higher than normal and may reflect the septic condition of the primary effluent entering the aeration tanks.

B. **Air Samples from Sludge Stream Processes.** Samples 8 and 9 were collected from the outlet and inlet, respectively, of the pre-engineered biofilter serving the gravity thickener and DAF thickener. Odor concentration was reduced from 7,900 to 5,300 D/T for an odor removal efficiency of only 33 percent. Based on laboratory data, the biofilter removed 85 percent of the

H_2S, but only 59 percent of the methyl mercaptan, 46 percent of the dimethyl sulfide, and 36 percent of the dimethyl disulfide. As the molecular weight of these compounds increases, they are more difficult to remove by either chemical or biological methods.

The belt press room exhaust showed moderate odor concentrations of 2,600 D/T and 1,400 D/T on the first and second days, respectively (Samples 4 and 11). Moderate amounts of methyl mercaptan and dimethyl sulfide were detected. Only one of the two roof-mounted exhaust fans was operating during the testing.

C. **Liquid Stream Sampling.** Table A-2 shows the results of influent wastewater analyses. Dissolved sulfide concentrations were in the range of 0.3 to 0.4 mg/L as estimated using color detector tubes. Oxidation-reduction potential (ORP) was consistently negative, indicative of anaerobic conditions. Review of the H_2S datalogger plot (Figure A-2) would suggest that dissolved sulfide concentrations are likely to be significantly higher during evening and early morning hours, resulting in greater release of H_2S to the atmosphere.

TABLE A-1

SUMMARY OF ODOR PANEL AND REDUCED SULFUR DATA
Odor Reducing Analysis and Study
Wastewater Treatment Facility, Kingston, NY

OCTOBER 1, 2002

SAMPLE NO.	TIME	LOCATION	ODOR CONCENTRATION D/T	REDUCED SULFUR COMPOUNDS,[1] PPB (EXCEPT WHERE NOTED)						
				H_2S, PPM (FIELD)	H_2S (LAB)	CS	MM	DMS	CS_2	DMDS
1	9:00 AM	Grit tank surface	4,300	2.0						
2	9:45 AM	Primary clarifier surface	1,200	0.08						
3	10:25 AM	Primary clarifier effluent channel	4,800	4.5	8,750	24.6	556	69.7	7.4	ND
4	11:20 AM	BFP room exhaust	2,600	0.35	268	8.08	55.6	18.4	5.18	ND
5	12:26 PM	Aeration tanks	1,600	0.025						
6	1:00 PM	First bar rack room	5,300	6.0						
7	1:10 PM	Second bar rack room	4,300	5.0						
8	1:35 PM	Biofilter outlet	5,300	0.4	120	8.48	712	554	ND	84.6
9	1:50 PM	Biofilter inlet	7,900	1.8	820	10.9	1,740	1,035	5.39	133
10	2:35 PM	Primary effluent pump station wet well	3,600	1.7						

OCTOBER 2, 2002

11	10:45 AM	BFP room exhaust	1,400	0.35	173	ND	30.2	11.3	ND	ND
12	12:30 PM	Grit tank surface	2,100	0.1						
13	12:50 PM	Degritter room exhaust	1,400	0.1	275	ND	7.64	ND	ND	ND
14	1:25 PM	Primary clarifier surface	1,000	0.3						
15	1:40 PM	Primary clarifier effluent channel	3,500	6.0						
16	2:15 PM	First bar rack room	3,200	4.0						

(1) H_2S Hydrogen sulfide; CS Carbonyl sulfide; MM Methyl mercaptan; DMS Dimethyl sulfide; CS_2 Carbon disulfide; DMDS Dimethyl disulfide

TABLE A-2

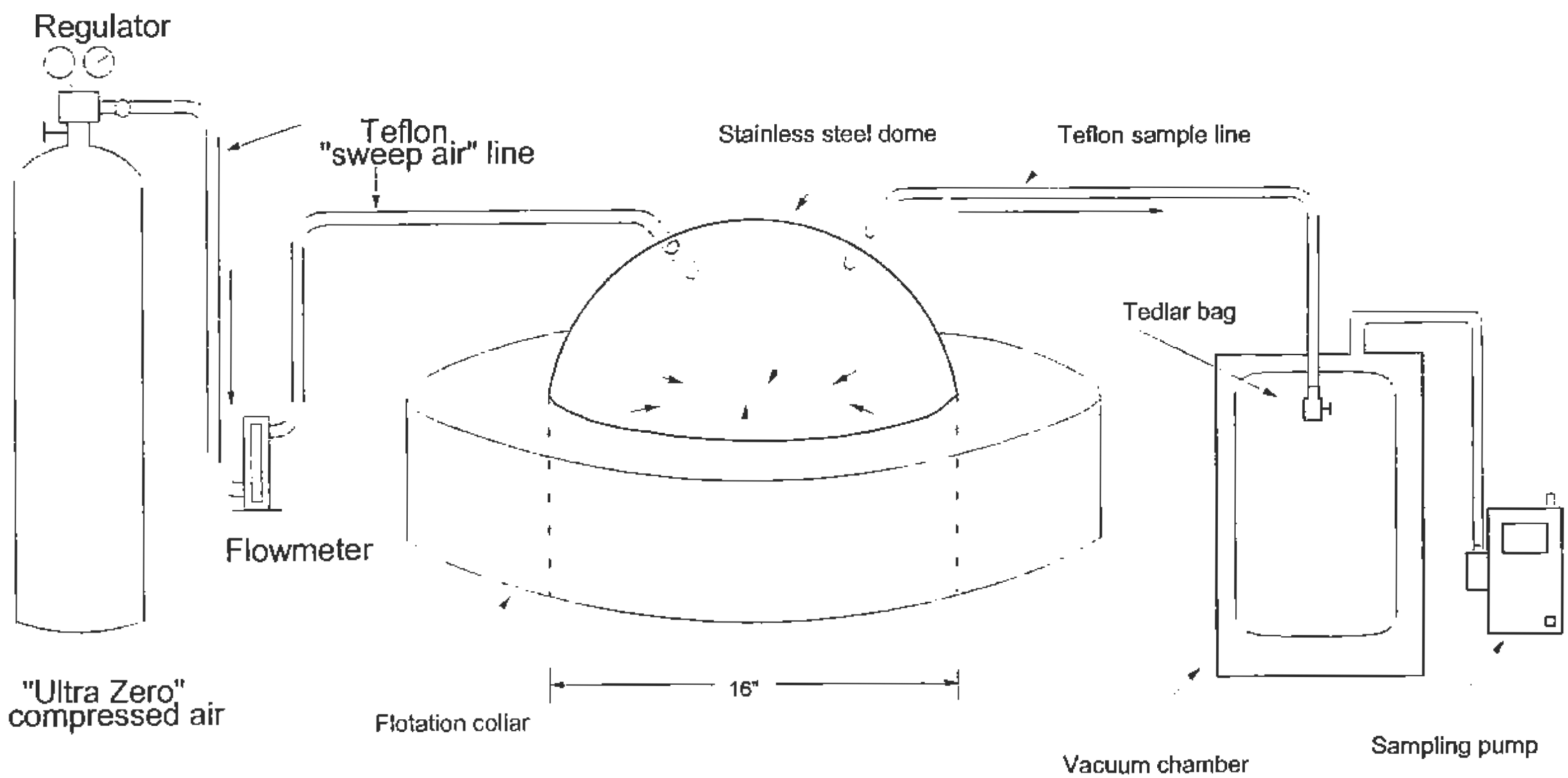
RESULTS OF INFLUENT WASTEWATER ANALYSIS
OCTOBER 1 AND 2, 2002
Odor Reducing Analysis and Study
Wastewater Treatment Facility, Kingston, NY

DATE	TIME	DISSOLVED SULFIDE (MG/L)	pH	ORP[1], mV	TEMPERATURE, °C
10/1/02	8:15 AM	0.3	7.2	-76	19.4
	10:55 AM	0.4	7.2	-87	21.3
	3:00 PM	0.4	7.1	-90	23.2
10/2/02	12:15 PM	0.4	7.0	-111	23.2
	2:10 PM	0.4	7.1	-106	23.6

(1) Negative ORP values indicative of septic wastewater conditions.

FIGURE A-1

DIAGRAM OF FLUX CHAMBER SAMPLING SYSTEM
Odor Reduction Analysis and Study
Wastewater Treatment Facility, Kingston, NY



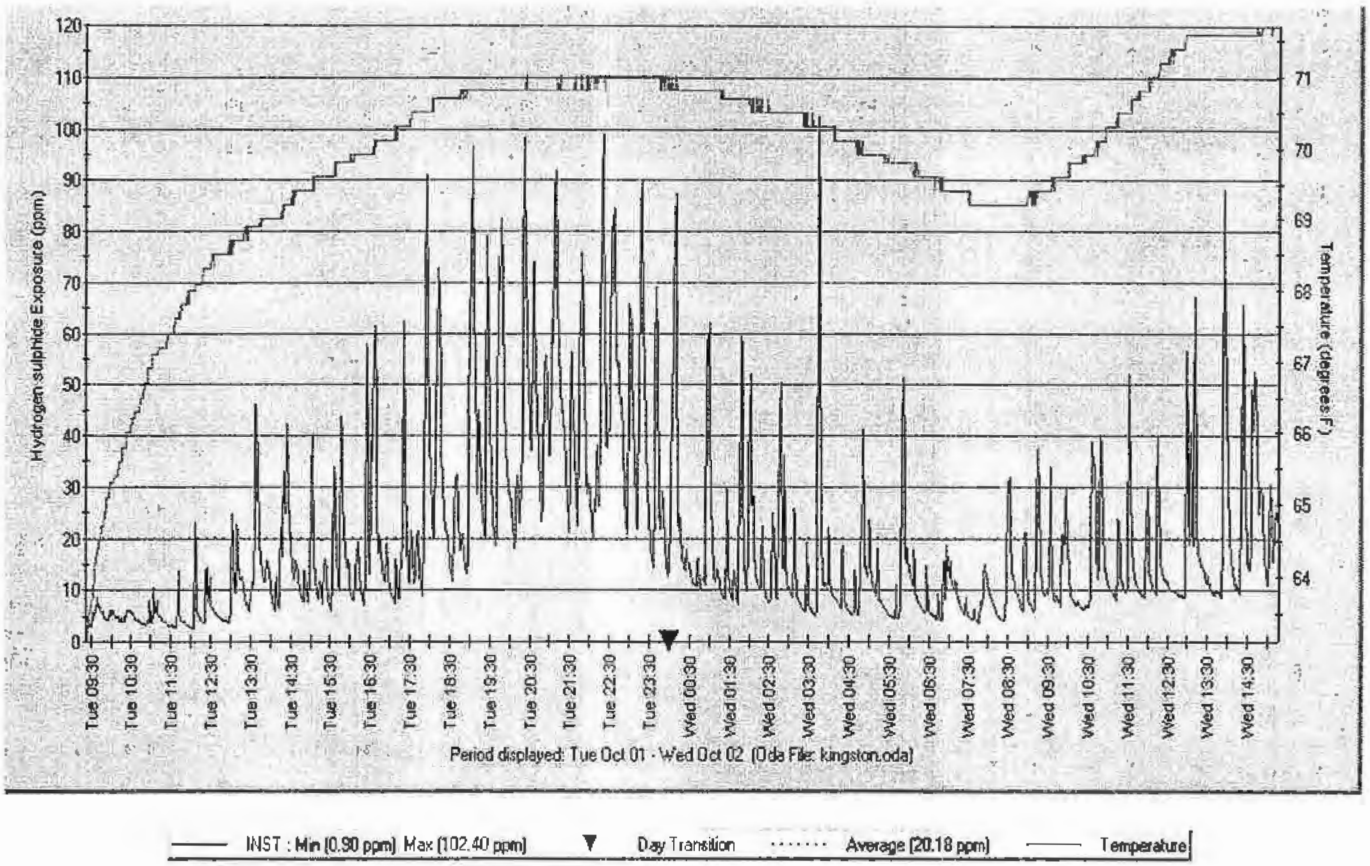
Source: Bowker & Associates, Inc.

2022410.1

FIGURE A-2

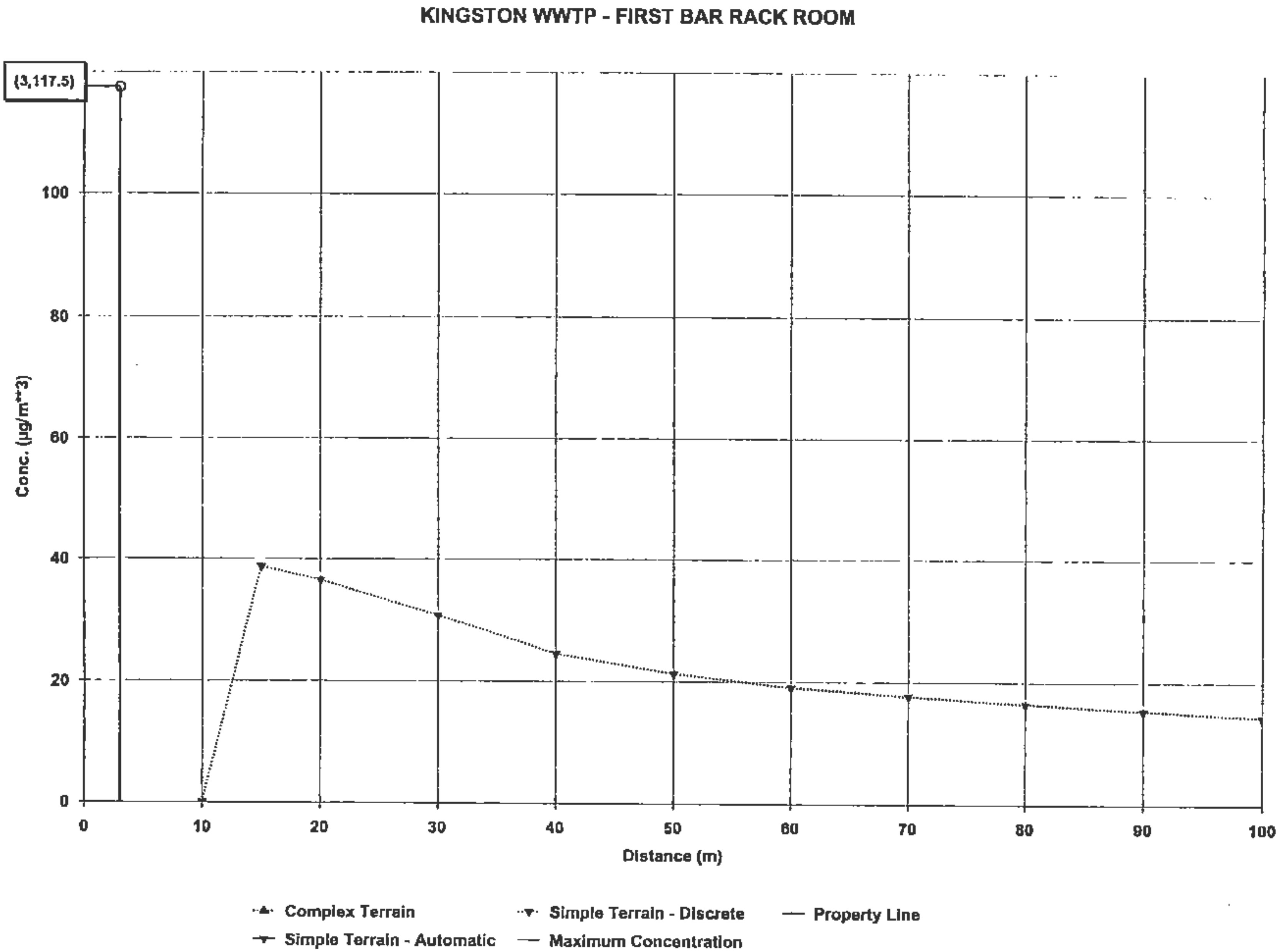
HYDROGEN SULFIDE LEVELS IN INFLUENT CHANNEL
Odor Reduction Analysis and Study
Wastewater Treatment Facility, Kingston, NY

Kingston, Influent to First Bar Rack (OdaLog: OL04051426)



APPENDIX B

ODOR DISPERSION MODELING RESULTS



KINGSTON WWTP - FIRST BAR RACK ROOM
(3,117.5)
100
80
60
40
20
0
Conc. (µg/m**3)
0
10
20
30
40
50
60
70
80
90
100
Distance (m)
Complex Terrain
Simple Terrain - Discrete
Property Line
Simple Terrain - Automatic
Maximum Concentration

12/20/2002
14:22:34

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

KINGSTON WWTP - FIRST BAR RACK ROOM ** 0

SIMPLE TERRAIN INPUTS:
SOURCE TYPE = POINT
EMISSION RATE (G/S) = 0.216100E-02
STACK HEIGHT (M) = 3.6576
STK INSIDE DIAM (M) = 3.0480
STK EXIT VELOCITY (M/S)= 0.0559
STK GAS EXIT TEMP (K) = 295.3722
AMBIENT AIR TEMP (K) = 294.2611
RECEPTOR HEIGHT (M) = 0.0000
URBAN/RURAL OPTION = RURAL
BUILDING HEIGHT (M) = 3.6576
MIN HORIZ BLDG DIM (M) = 3.3528
MAX HORIZ BLDG DIM (M) = 6.0960

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

STACK EXIT VELOCITY WAS CALCULATED FROM
VOLUME FLOW RATE = 0.40776259 (M**3/S)

BUOY. FLUX = 0.005 M**4/S**3; MOM. FLUX = 0.007 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
10.	0.000	0	0.0	0.0	0.0	0.00	0.00	0.00	NA
15.	38.69	3	1.0	1.0	320.0	3.66	2.70	2.80	SS
20.	36.52	3	1.0	1.0	320.0	3.66	3.04	3.13	SS
30.	30.70	4	1.0	1.0	320.0	3.66	3.71	3.79	SS
40.	24.45	4	1.0	1.0	320.0	3.66	4.50	4.48	SS
50.	21.25	6	1.0	1.0	10000.0	4.09	4.75	4.55	SS
60.	19.03	6	1.0	1.0	10000.0	4.24	5.12	4.71	SS
70.	17.63	6	1.0	1.0	10000.0	4.24	5.49	4.86	SS
80.	16.39	6	1.0	1.0	10000.0	4.24	5.86	5.01	SS
90.	15.29	6	1.0	1.0	10000.0	4.24	6.22	5.17	SS
100.	14.30	6	1.0	1.0	10000.0	4.24	6.58	5.32	SS

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

```
****************************************
  *** REGULATORY (Default) ***
  PERFORMING CAVITY CALCULATIONS
 WITH ORIGINAL SCREEN CAVITY MODEL
      (BRODE, 1988)
****************************************


*** CAVITY CALCULATION - 1 ***      *** CAVITY CALCULATION - 2 ***
 CONC (UG/M**3)    =   64.61       CONC (UG/M**3)    =   117.5
 CRIT WS @10M (M/S) =    1.00      CRIT WS @10M (M/S) =    1.00
 CRIT WS @ HS (M/S) =    1.00      CRIT WS @ HS (M/S) =    1.00
 DILUTION WS (M/S)  =    1.00      DILUTION WS (M/S)  =    1.00
 CAVITY HT (M)      =    5.43      CAVITY HT (M)      =    4.33
 CAVITY LENGTH (M)  =    8.66      CAVITY LENGTH (M)  =    3.42
 ALONGWIND DIM (M)  =    3.35      ALONGWIND DIM (M)  =    6.10

****************************************
  END OF CAVITY CALCULATIONS
****************************************


  ***************************************
  *** SUMMARY OF SCREEN MODEL RESULTS ***
  ***************************************

 CALCULATION      MAX CONC    DIST TO   TERRAIN
  PROCEDURE      (UG/M**3)    MAX (M)   HT (M)
--------------   ----------   -------   -------
SIMPLE TERRAIN     38.69         15.        0.

BLDG. CAVITY-1     64.61          9.       -- (DIST = CAVITY LENGTH)

BLDG. CAVITY-2     117.5          3.       -- (DIST = CAVITY LENGTH)


***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
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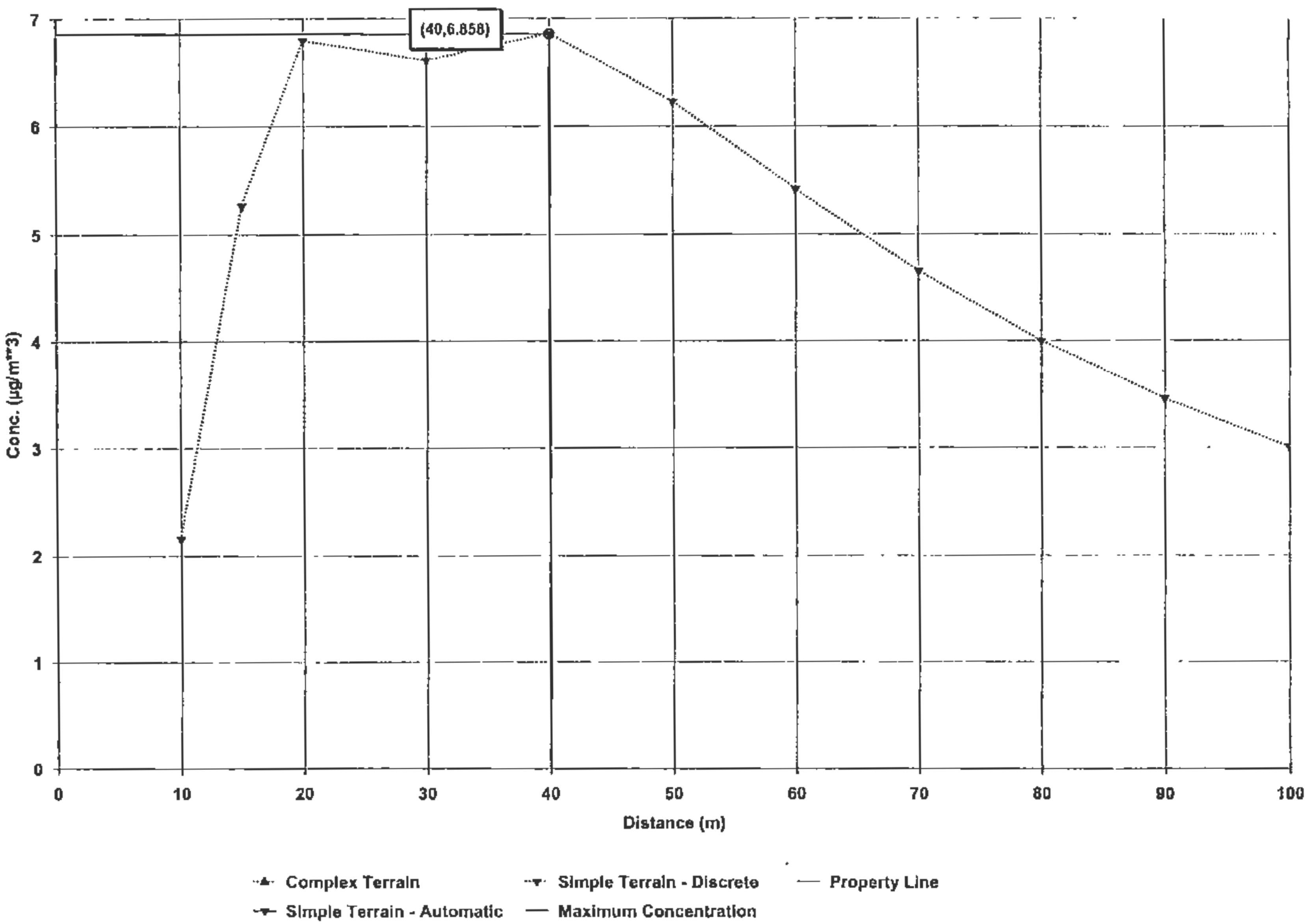
KINGSTON WWTP - GRIT CHAMBER



12/20/2002
14:26:01

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

KINGSTON WWTP - GRIT CHAMBER ** 0

SIMPLE TERRAIN INPUTS:
SOURCE TYPE = AREA
EMISSION RATE (G/(S-M**2)) = 0.290000E-05
SOURCE HEIGHT (M) = 1.2192
LENGTH OF LARGER SIDE (M) = 6.2179
LENGTH OF SMALLER SIDE (M) = 6.2179
RECEPTOR HEIGHT (M) = 0.0000
URBAN/RURAL OPTION = RURAL
THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

MODEL ESTIMATES DIRECTION TO MAX CONCENTRATION

BUOY. FLUX = 0.000 M**4/S**3; MOM. FLUX = 0.000 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

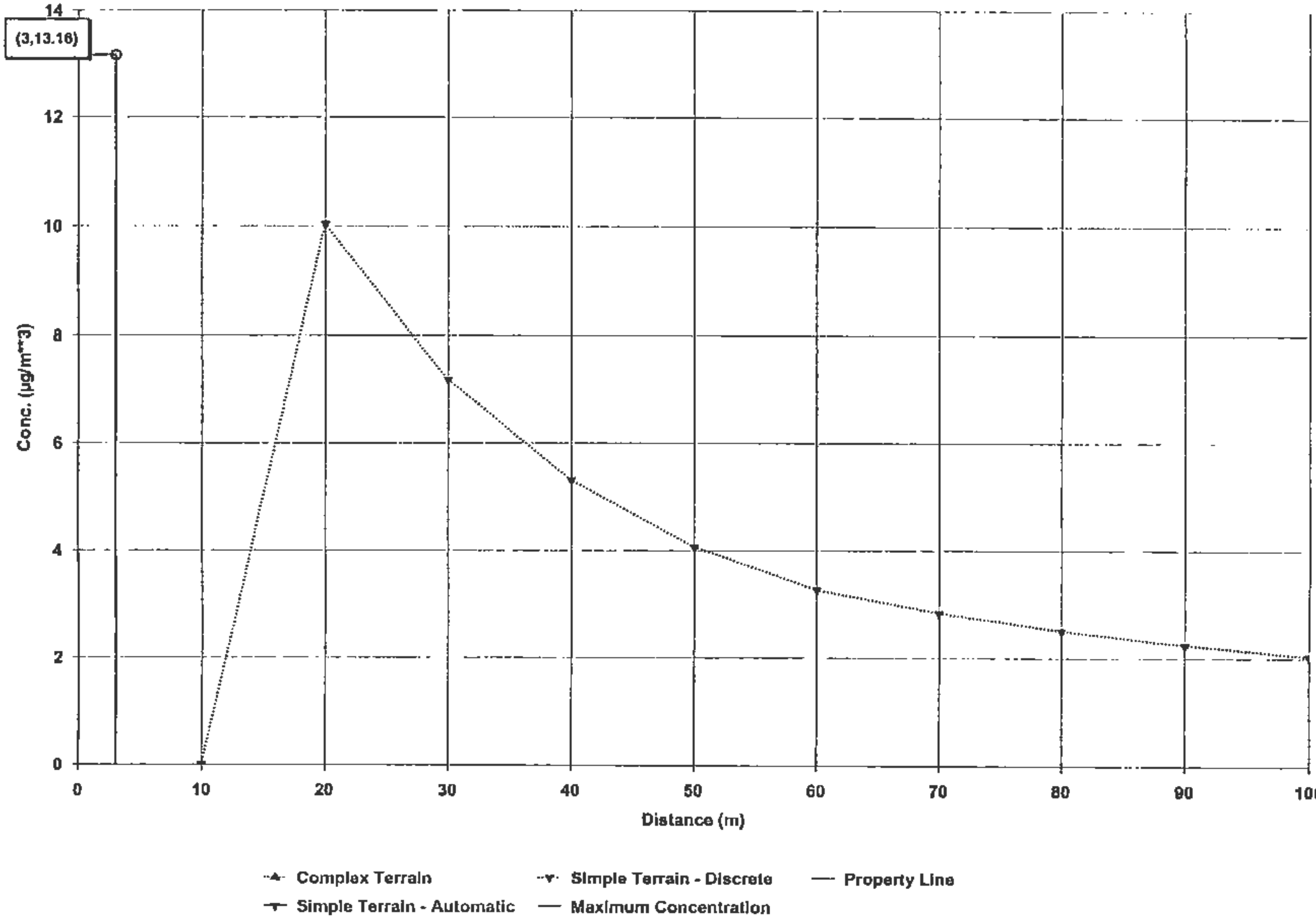
DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	MAX DIR (DEG)
10.	2.157	5	1.0	1.0	10000.0	1.22	45.
15.	5.264	5	1.0	1.0	10000.0	1.22	45.
20.	6.794	5	1.0	1.0	10000.0	1.22	45.
30.	6.606	6	1.0	1.0	10000.0	1.22	45.
40.	6.858	6	1.0	1.0	10000.0	1.22	45.
50.	6.227	6	1.0	1.0	10000.0	1.22	44.
60.	5.415	6	1.0	1.0	10000.0	1.22	45.
70.	4.652	6	1.0	1.0	10000.0	1.22	45.
80.	3.996	6	1.0	1.0	10000.0	1.22	44.
90.	3.451	6	1.0	1.0	10000.0	1.22	42.
100.	3.000	6	1.0	1.0	10000.0	1.22	45.

****
*** SUMMARY OF SCREEN MODEL RESULTS ***
****

CALCULATION PROCEDURE	MAX CONC (UG/M**3)	DIST TO MAX (M)	TERRAIN HT (M)
SIMPLE TERRAIN	6.858	40.	0.

****

KINGSTON WWTP - DEGRITTER BUILDING



12/20/2002
14:17:04

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

KINGSTON WWTP - DEGRITTER BUILDING ** 0

SIMPLE TERRAIN INPUTS:
SOURCE TYPE = POINT
EMISSION RATE (G/S) = 0.198000E-03
STACK HEIGHT (M) = 3.6576
STK INSIDE DIAM (M) = 1.2192
STK EXIT VELOCITY (M/S)= 0.5134
STK GAS EXIT TEMP (K) = 295.3722
AMBIENT AIR TEMP (K) = 294.2611
RECEPTOR HEIGHT (M) = 0.0000
URBAN/RURAL OPTION = RURAL
BUILDING HEIGHT (M) = 3.6576
MIN HORIZ BLDG DIM (M) = 2.7432
MAX HORIZ BLDG DIM (M) = 5.1816

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

STACK EXIT VELOCITY WAS CALCULATED FROM
VOLUME FLOW RATE = 0.59937328 (M**3/S)

BUOY. FLUX = 0.007 M**4/S**3; MOM. FLUX = 0.098 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
10.	0.000	0	0.0	0.0	0.0	0.00	0.00	0.00	NA
20.	10.04	6	1.0	1.0	10000.0	3.79	0.91	2.84	SS
30.	7.161	6	1.0	1.0	10000.0	3.94	1.33	3.45	SS
40.	5.306	6	1.0	1.0	10000.0	4.14	1.74	4.00	SS
50.	4.066	6	1.0	1.0	10000.0	4.39	2.14	4.16	SS
60.	3.254	6	1.0	1.0	10000.0	4.62	2.53	4.32	SS
70.	2.830	6	1.0	1.0	10000.0	4.62	2.92	4.48	SS
80.	2.502	6	1.0	1.0	10000.0	4.62	3.31	4.63	SS
90.	2.240	6	1.0	1.0	10000.0	4.62	3.69	4.79	SS
100.	2.026	6	1.0	1.0	10000.0	4.62	4.07	4.94	SS

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

```
****************************************
   *** REGULATORY (Default) ***
  PERFORMING CAVITY CALCULATIONS
 WITH ORIGINAL SCREEN CAVITY MODEL
      (BRODE, 1988)
****************************************


*** CAVITY CALCULATION - 1 ***       *** CAVITY CALCULATION - 2 ***
 CONC (UG/M**3)     =   6.965       CONC (UG/M**3)     =   13.16
 CRIT WS @10M (M/S) =    1.00       CRIT WS @10M (M/S) =    1.00
 CRIT WS @ HS (M/S) =    1.00       CRIT WS @ HS (M/S) =    1.00
 DILUTION WS (M/S)  =    1.00       DILUTION WS (M/S)  =    1.00
 CAVITY HT (M)      =    5.86       CAVITY HT (M)      =    4.59
 CAVITY LENGTH (M)  =    8.50       CAVITY LENGTH (M)  =    3.25
 ALONGWIND DIM (M)  =    2.74       ALONGWIND DIM (M)  =    5.18

****************************************
   END OF CAVITY CALCULATIONS
****************************************

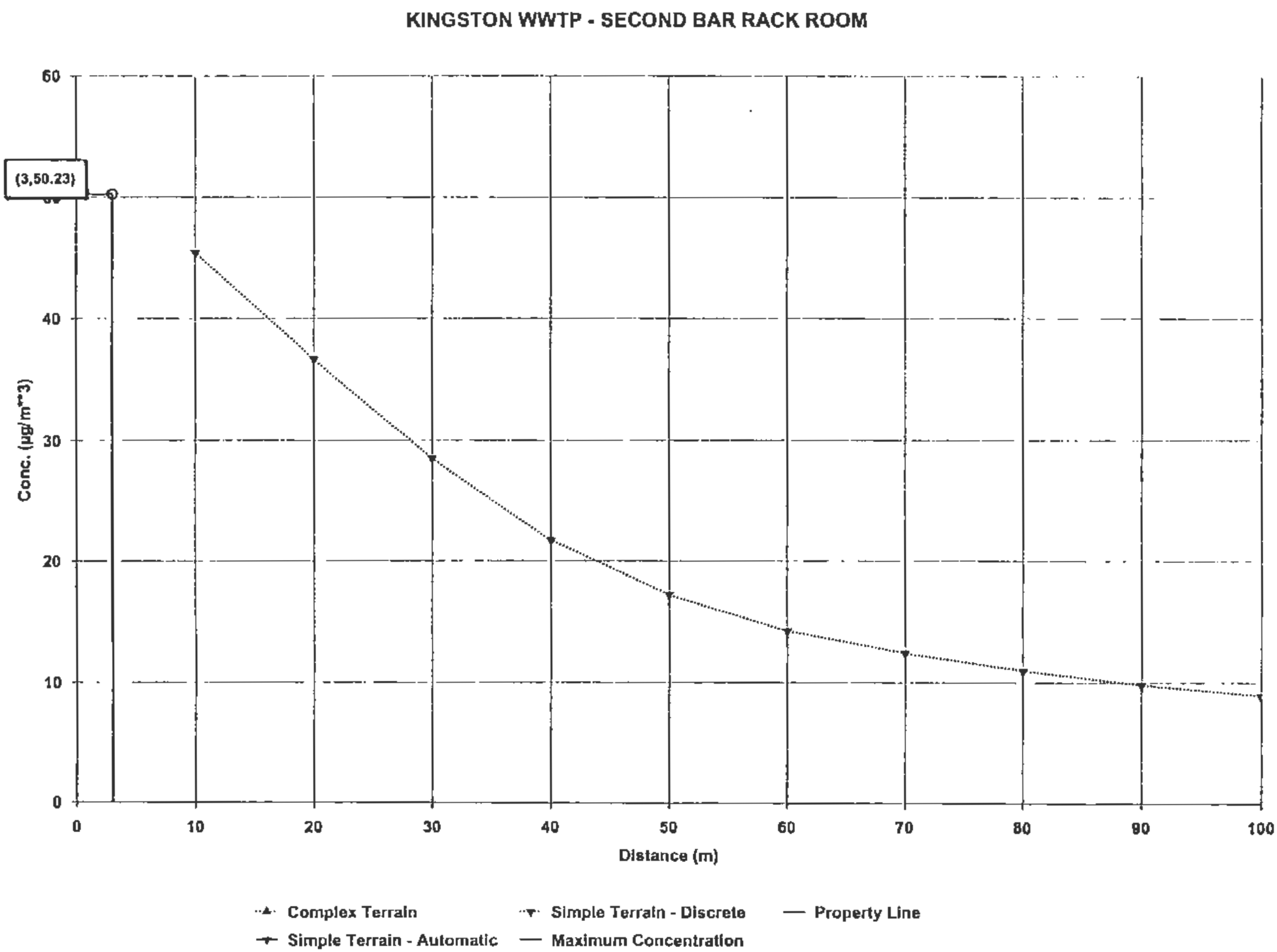

   ***************************************
   *** SUMMARY OF SCREEN MODEL RESULTS ***
   ***************************************

 CALCULATION       MAX CONC    DIST TO   TERRAIN
  PROCEDURE       (UG/M**3)    MAX (M)    HT (M)
--------------   ----------   -------   -------
SIMPLE TERRAIN      10.04        20.        0.

BLDG. CAVITY-1      6.965         9.       --   (DIST = CAVITY LENGTH)

BLDG. CAVITY-2      13.16         3.       --   (DIST = CAVITY LENGTH)


***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
***************************************************
```



KINGSTON WWTP - SECOND BAR RACK ROOM
(3,50.23)
Conc. (µg/m**3)
0
10
20
30
40
60
Distance (m)
0
10
20
30
40
50
60
70
80
90
100
Complex Terrain
Simple Terrain - Automatic
Simple Terrain - Discrete
Maximum Concentration
Property Line

12/20/2002
14:15:23

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

KINGSTON WWTP - SECOND BAR RACK ROOM ** 0

SIMPLE TERRAIN INPUTS:

```
SOURCE TYPE          =    POINT
EMISSION RATE (G/S)  =    0.770000E-03
STACK HEIGHT (M)     =    3.6576
STK INSIDE DIAM (M)  =    2.4384
STK EXIT VELOCITY (M/S)=  0.0384
STK GAS EXIT TEMP (K) =   295.3722
AMBIENT AIR TEMP (K)  =   294.2611
RECEPTOR HEIGHT (M)   =   0.0000
URBAN/RURAL OPTION    =   RURAL
BUILDING HEIGHT (M)   =   3.0480
MIN HORIZ BLDG DIM (M) =  3.3528
MAX HORIZ BLDG DIM (M) =  5.1816
```

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

STACK EXIT VELOCITY WAS CALCULATED FROM
VOLUME FLOW RATE = 0.17934000 (M**3/S)

BUOY. FLUX = 0.002 M**4/S**3; MOM. FLUX = 0.002 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
10.	45.39	6	1.0	1.0	10000.0	3.67	0.48	1.96	SS
20.	36.69	6	1.0	1.0	10000.0	3.71	0.91	2.56	SS
30.	28.50	6	1.0	1.0	10000.0	3.78	1.33	3.16	SS
40.	21.73	6	1.0	1.0	10000.0	3.88	1.74	3.43	SS
50.	17.22	6	1.0	1.0	10000.0	3.99	2.14	3.61	SS
60.	14.19	6	1.0	1.0	10000.0	4.11	2.53	3.78	SS
70.	12.36	6	1.0	1.0	10000.0	4.11	2.92	3.95	SS
80.	10.94	6	1.0	1.0	10000.0	4.11	3.31	4.09	SS
90.	9.796	6	1.0	1.0	10000.0	4.11	3.69	4.25	SS
100.	8.852	6	1.0	1.0	10000.0	4.11	4.07	4.41	SS

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

****

*** REGULATORY (Default) ***
PERFORMING CAVITY CALCULATIONS
WITH ORIGINAL SCREEN CAVITY MODEL
(BRODE, 1988)

****

*** CAVITY CALCULATION - 1 ***	*** CAVITY CALCULATION - 2 ***
CONC (UG/M**3) = 32.50	CONC (UG/M**3) = 50.23
CRIT WS @10M (M/S) = 1.00	CRIT WS @10M (M/S) = 1.00
CRIT WS @ HS (M/S) = 1.00	CRIT WS @ HS (M/S) = 1.00
DILUTION WS (M/S) = 1.00	DILUTION WS (M/S) = 1.00
CAVITY HT (M) = 4.22	CAVITY HT (M) = 3.58
CAVITY LENGTH (M) = 6.58	CAVITY LENGTH (M) = 3.30
ALONGWIND DIM (M) = 3.35	ALONGWIND DIM (M) = 5.18

****

END OF CAVITY CALCULATIONS

****

****

*** SUMMARY OF SCREEN MODEL RESULTS ***

****

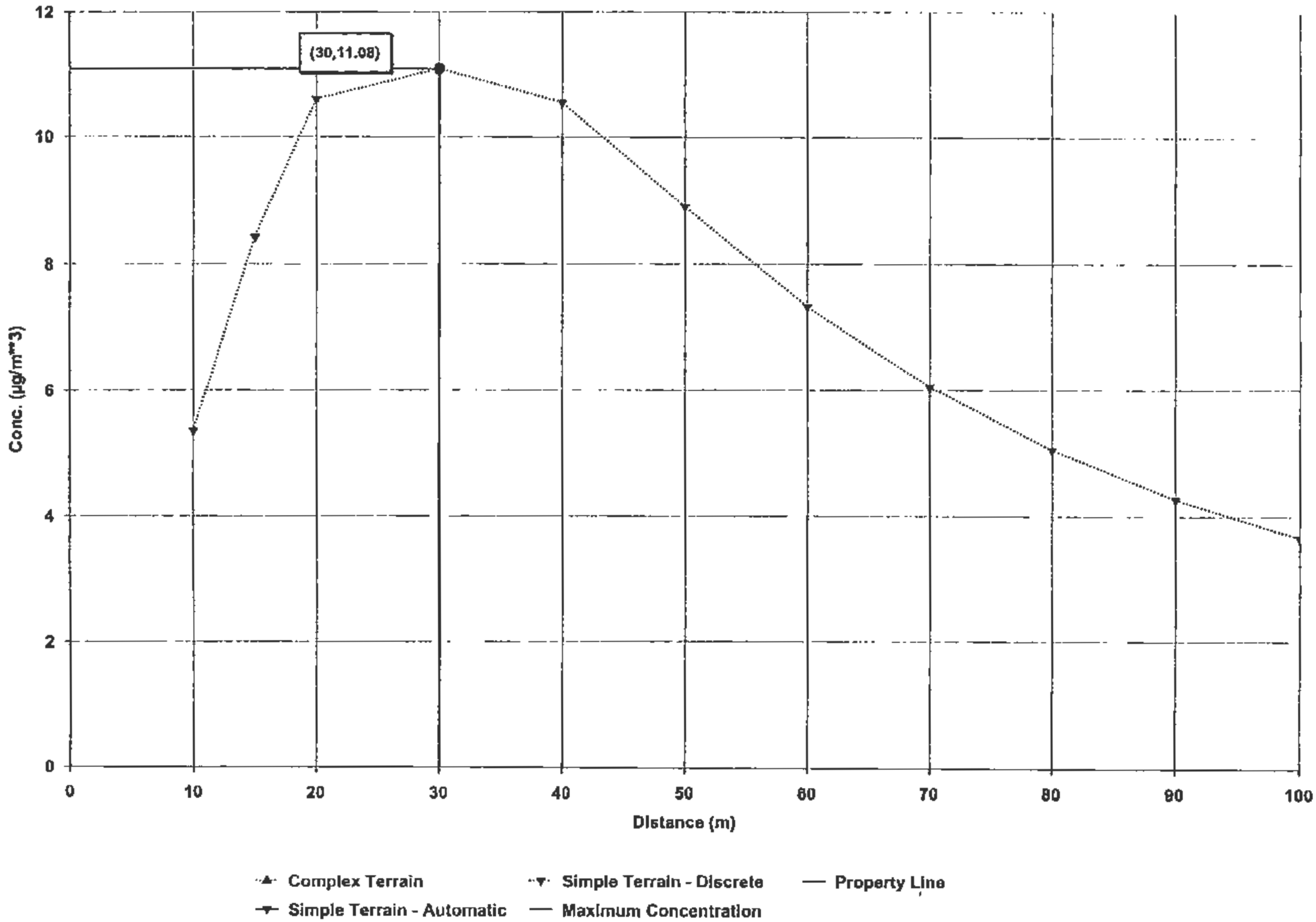
CALCULATION PROCEDURE	MAX CONC (UG/M**3)	DIST TO MAX (M)	TERRAIN HT (M)
SIMPLE TERRAIN	45.39	10.	0.
BLDG. CAVITY-1	32.50	7.	-- (DIST = CAVITY LENGTH)
BLDG. CAVITY-2	50.23	3.	-- (DIST = CAVITY LENGTH)

****

** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **

****

KINGSTON WWTP - PRIMARY CLARIFIERS - LAUNDERS



12/20/2002
14:24:57

```
***  SCREEN3 MODEL RUN  ***
*** VERSION DATED 96043 ***

KINGSTON WWTP - PRIMARY CLARIFIERS - LAUNDERS ** 0

SIMPLE TERRAIN INPUTS:
   SOURCE TYPE              =        AREA
   EMISSION RATE (G/(S-M**2)) =    0.311200E-05
   SOURCE HEIGHT (M)        =      1.2192
   LENGTH OF LARGER SIDE (M)  =     18.8976
   LENGTH OF SMALLER SIDE (M)  =     2.1336
   RECEPTOR HEIGHT (M)      =      0.0000
   URBAN/RURAL OPTION       =       RURAL
THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

  MODEL ESTIMATES DIRECTION TO MAX CONCENTRATION


BUOY. FLUX =    0.000 M**4/S**3;  MOM. FLUX =    0.000 M**4/S**2.

*** FULL METEOROLOGY ***

**********************************
*** SCREEN DISCRETE DISTANCES ***
**********************************

*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

 DIST    CONC          U10M   USTK  MIX HT   PLUME  MAX DIR
  (M)  (UG/M**3)  STAB  (M/S)  (M/S)   (M)   HT (M)   (DEG)
-------  ----------  ----  -----  -----  -------  ------  -------
   10.   5.351      5    1.0    1.0 10000.0    1.22      0.
   15.   8.419      5    1.0    1.0 10000.0    1.22      0.
   20.   10.59      5    1.0    1.0 10000.0    1.22      0.
   30.   11.08      6    1.0    1.0 10000.0    1.22      0.
   40.   10.54      6    1.0    1.0 10000.0    1.22      0.
   50.   8.896      6    1.0    1.0 10000.0    1.22      0.
   60.   7.328      6    1.0    1.0 10000.0    1.22      0.
   70.   6.052      6    1.0    1.0 10000.0    1.22      0.
   80.   5.052      6    1.0    1.0 10000.0    1.22      0.
   90.   4.270      6    1.0    1.0 10000.0    1.22      0.
  100.   3.652      6    1.0    1.0 10000.0    1.22      0.

   ***************************************
   *** SUMMARY OF SCREEN MODEL RESULTS ***
   ***************************************

 CALCULATION        MAX CONC    DIST TO   TERRAIN
  PROCEDURE        (UG/M**3)    MAX (M)    HT (M)
 --------------    -----------   -------   -------
 SIMPLE TERRAIN      11.08          30.        0.

***************************************************
```

12/20/2002
14:18:45

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

KINGSTON WWTP - PRIMARY EFFLUENT PS ** 0

SIMPLE TERRAIN INPUTS:
SOURCE TYPE = POINT
EMISSION RATE (G/S) = 0.317200E-02
STACK HEIGHT (M) = 4.8768
STK INSIDE DIAM (M) = 1.2192
STK EXIT VELOCITY (M/S)= 1.9404
STK GAS EXIT TEMP (K) = 294.2611
AMBIENT AIR TEMP (K) = 294.2611
RECEPTOR HEIGHT (M) = 0.0000
URBAN/RURAL OPTION = RURAL
BUILDING HEIGHT (M) = 4.8768
MIN HORIZ BLDG DIM (M) = 9.7536
MAX HORIZ BLDG DIM (M) = 9.7536

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

STACK EXIT VELOCITY WAS CALCULATED FROM
VOLUME FLOW RATE = 2.2653480 (M**3/S)

BUOY. FLUX = 0.000 M**4/S**3; MOM. FLUX = 1.399 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
10.	0.000	0	0.0	0.0	0.0	0.00	0.00	0.00	NA
20.	50.19	6	1.5	1.5	10000.0	5.14	0.91	2.82	SS
30.	44.02	6	1.5	1.5	10000.0	5.24	1.33	3.33	SS
40.	38.44	6	1.5	1.5	10000.0	5.33	1.74	3.83	SS
50.	33.80	6	1.5	1.5	10000.0	5.39	2.14	4.40	SS
60.	28.70	6	1.5	1.5	10000.0	5.43	2.53	4.56	SS
70.	25.12	6	1.5	1.5	10000.0	5.44	2.92	4.71	SS
80.	22.39	6	1.5	1.5	10000.0	5.44	3.31	4.87	SS
90.	20.21	6	1.5	1.5	10000.0	5.44	3.69	5.02	SS
100.	18.40	6	1.5	1.5	10000.0	5.44	4.07	5.17	SS

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

****

*** REGULATORY (Default) ***
PERFORMING CAVITY CALCULATIONS
WITH ORIGINAL SCREEN CAVITY MODEL
(BRODE, 1988)

****

*** CAVITY CALCULATION - 1 ***	*** CAVITY CALCULATION - 2 ***
CONC (UG/M**3) = 44.46	CONC (UG/M**3) = 44.46
CRIT WS @10M (M/S) = 1.94	CRIT WS @10M (M/S) = 1.94
CRIT WS @ HS (M/S) = 1.94	CRIT WS @ HS (M/S) = 1.94
DILUTION WS (M/S) = 1.00	DILUTION WS (M/S) = 1.00
CAVITY HT (M) = 5.46	CAVITY HT (M) = 5.46
CAVITY LENGTH (M) = 11.38	CAVITY LENGTH (M) = 11.38
ALONGWIND DIM (M) = 9.75	ALONGWIND DIM (M) = 9.75

****

END OF CAVITY CALCULATIONS

****

****

*** SUMMARY OF SCREEN MODEL RESULTS ***

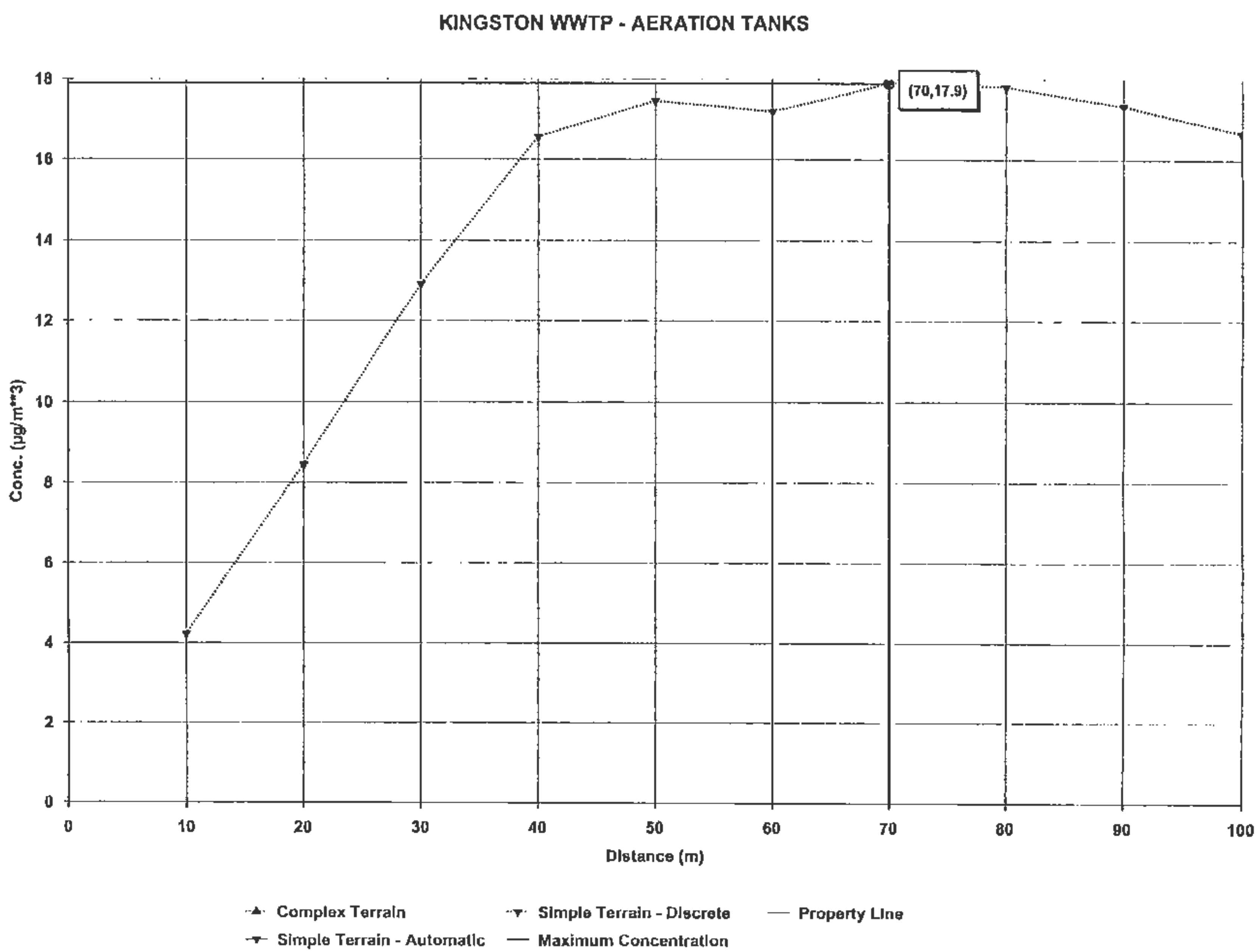
****

CALCULATION PROCEDURE	MAX CONC (UG/M**3)	DIST TO MAX (M)	TERRAIN HT (M)
SIMPLE TERRAIN	50.19	20.	0.
BLDG. CAVITY-1	44.46	11.	-- (DIST = CAVITY LENGTH)
BLDG. CAVITY-2	44.46	11.	-- (DIST = CAVITY LENGTH)

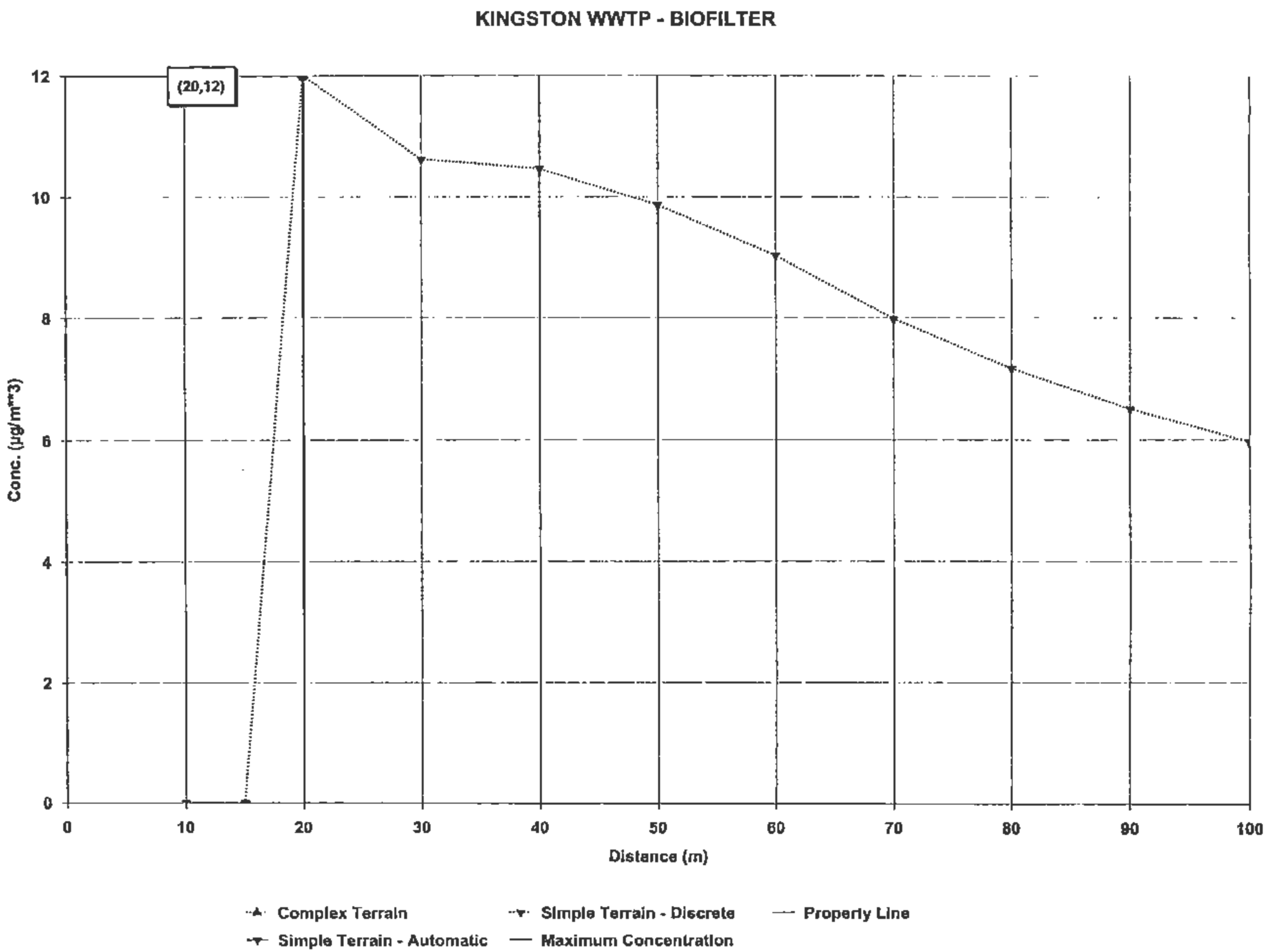
****

** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **

****



KINGSTON WWTP - AERATION TANKS
(70,17.9)
Conc. (µg/m**3)
Distance (m)
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
50
60
70
80
90
100
Complex Terrain
Simple Terrain - Discrete
Property Line
Simple Terrain - Automatic
Maximum Concentration


KINGSTON WWTP - BIOFILTER
(20,12)
Conc. (µg/m**3)
Distance (m)
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70
80
90
100
Complex Terrain
Simple Terrain - Discrete
Property Line
Simple Terrain - Automatic
Maximum Concentration

12/20/2002
14:21:09

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

KINGSTON WWTP - BIOFILTER ** 0

SIMPLE TERRAIN INPUTS:
SOURCE TYPE = POINT
EMISSION RATE (G/S) = 0.750000E-03
STACK HEIGHT (M) = 5.4864
STK INSIDE DIAM (M) = 0.1524
STK EXIT VELOCITY (M/S)= 7.7617
STK GAS EXIT TEMP (K) = 295.3722
AMBIENT AIR TEMP (K) = 294.2611
RECEPTOR HEIGHT (M) = 0.0000
URBAN/RURAL OPTION = RURAL
BUILDING HEIGHT (M) = 5.4864
MIN HORIZ BLDG DIM (M) = 18.2880
MAX HORIZ BLDG DIM (M) = 24.3840

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

STACK EXIT VELOCITY WAS CALCULATED FROM
VOLUME FLOW RATE = 0.14158420 (M**3/S)

BUOY. FLUX = 0.002 M**4/S**3; MOM. FLUX = 0.348 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
10.	0.000	0	0.0	0.0	0.0	0.00	0.00	0.00	NA
15.	0.000	0	0.0	0.0	0.0	0.00	0.00	0.00	NA
20.	12.00	6	1.5	1.5	10000.0	5.57	0.91	3.20	SS
30.	10.61	6	1.0	1.0	10000.0	5.86	1.33	3.21	SS
40.	10.46	6	1.0	1.0	10000.0	5.86	1.74	3.67	SS
50.	9.861	6	1.0	1.0	10000.0	5.86	2.14	4.12	SS
60.	9.023	6	1.0	1.0	10000.0	5.86	2.53	4.53	SS
70.	7.982	6	1.0	1.0	10000.0	5.86	2.92	4.69	SS
80.	7.169	6	1.0	1.0	10000.0	5.86	3.31	4.84	SS
90.	6.510	6	1.0	1.0	10000.0	5.86	3.69	5.00	SS
100.	5.963	6	1.0	1.0	10000.0	5.86	4.07	5.15	SS

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

```
****************************************
   *** REGULATORY (Default) ***
  PERFORMING CAVITY CALCULATIONS
 WITH ORIGINAL SCREEN CAVITY MODEL
      (BROOE, 1988)
****************************************


*** CAVITY CALCULATION - 1 ***       *** CAVITY CALCULATION - 2 ***
 CONC (UG/M**3)    =  0.7247       CONC (UG/M**3)    =  0.8394
 CRIT WS @10M (M/S) =   10.31       CRIT WS @10M (M/S) =   11.87
 CRIT WS @ HS (M/S) =   10.31       CRIT WS @ HS (M/S) =   11.87
 DILUTION WS (M/S)  =   5.16       DILUTION WS (M/S)  =   5.94
 CAVITY HT (M)      =   5.60       CAVITY HT (M)      =   5.51
 CAVITY LENGTH (M)  =  20.21       CAVITY LENGTH (M)  =  17.46
 ALONGWIND DIM (M)  =  18.29       ALONGWIND DIM (M)  =  24.38

****************************************
   END OF CAVITY CALCULATIONS
****************************************

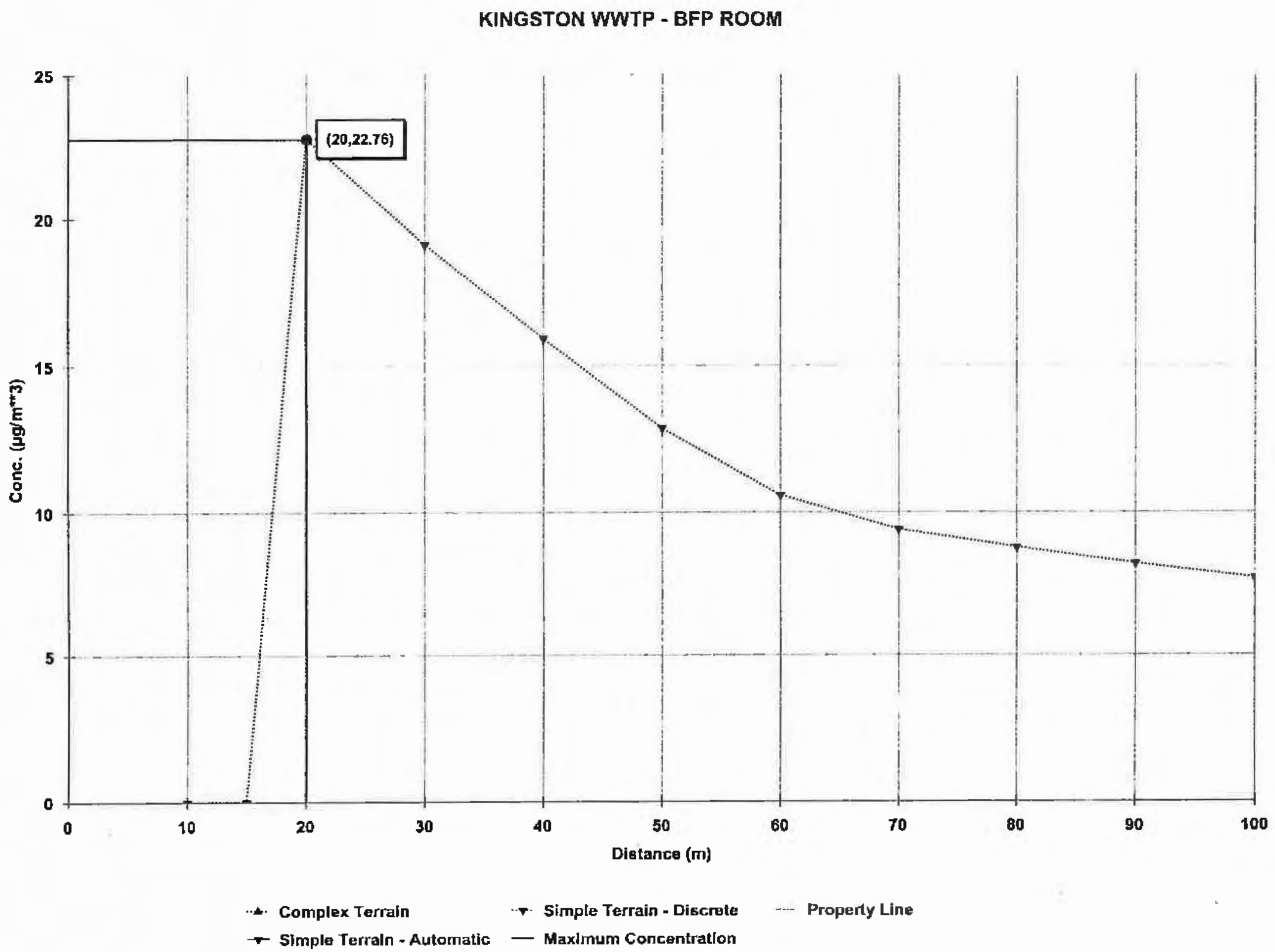

   ****************************************
   *** SUMMARY OF SCREEN MODEL RESULTS ***
   ****************************************

 CALCULATION      MAX CONC   DIST TO   TERRAIN
  PROCEDURE       (UG/M**3)  MAX (M)   HT (M)
--------------   --------   -------   ------
SIMPLE TERRAIN    12.00        20.       0.

BLDG. CAVITY-1    0.7247       20.      --  (DIST = CAVITY LENGTH)

BLDG. CAVITY-2    0.8394       17.      --  (DIST = CAVITY LENGTH)


***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
***************************************************
```


KINGSTON WWTP - BFP ROOM
(20,22.76)
Conc. (µg/m**3)
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Distance (m)
Complex Terrain
Simple Terrain - Discrete
Property Line
Simple Terrain - Automatic
Maximum Concentration

01/23/2003
14:35:11

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

KINGSTON WWTP - BFP ROOM ** 0

SIMPLE TERRAIN INPUTS:
SOURCE TYPE = POINT
EMISSION RATE (G/S) = 0.158600E-02
STACK HEIGHT (M) = 5.4864
STK INSIDE DIAM (M) = 3.6576
STK EXIT VELOCITY (M/S)= 0.1078
STK GAS EXIT TEMP (K) = 295.3722
AMBIENT AIR TEMP (K) = 294.2611
RECEPTOR HEIGHT (M) = 0.0000
URBAN/RURAL OPTION = RURAL
BUILDING HEIGHT (M) = 5.4864
MIN HORIZ BLDG DIM (M) = 18.2880
MAX HORIZ BLDG DIM (M) = 24.3840

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

STACK EXIT VELOCITY WAS CALCULATED FROM
VOLUME FLOW RATE = 1.1326740 (M**3/S)

BUOY. FLUX = 0.013 M**4/S**3; MOM. FLUX = 0.039 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
10.	0.000	0	0.0	0.0	0.0	0.00	0.00	0.00	NA
15.	0.000	0	0.0	0.0	0.0	0.00	0.00	0.00	NA
20.	22.76	4	1.0	1.0	320.0	5.49	2.16	3.99	SS
30.	19.12	4	1.0	1.0	320.0	5.49	2.83	4.64	SS
40.	15.91	4	1.0	1.0	320.0	5.49	3.50	5.30	SS
50.	12.86	4	1.0	1.0	320.0	5.49	4.31	5.95	SS
60.	10.58	4	1.0	1.0	320.0	5.49	5.11	6.64	SS
70.	9.395	6	1.0	1.0	10000.0	6.23	5.21	6.65	SS
80.	8.749	6	1.0	1.0	10000.0	6.23	5.58	6.79	SS
90.	8.181	6	1.0	1.0	10000.0	6.23	5.94	6.93	SS
100.	7.677	6	1.0	1.0	10000.0	6.23	6.31	7.07	SS

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

```
****************************************
   *** REGULATORY (Default) ***
  PERFORMING CAVITY CALCULATIONS
 WITH ORIGINAL SCREEN CAVITY MODEL
      (BRODE, 1988)
****************************************


*** CAVITY CALCULATION - 1 ***      *** CAVITY CALCULATION - 2 ***
 CONC (UG/M**3)     =   7.904       CONC (UG/M**3)      =    10.54
 CRIT WS @10M (M/S) =    1.00       CRIT WS @10M (M/S) =    1.00
 CRIT WS @ HS (M/S) =    1.00       CRIT WS @ HS (M/S) =    1.00
 DILUTION WS (M/S)  =    1.00       DILUTION WS (M/S)  =    1.00
 CAVITY HT (M)      =    5.60       CAVITY HT (M)      =    5.51
 CAVITY LENGTH (M)  =   20.21       CAVITY LENGTH (M)  =   17.46
 ALONGWIND DIM (M)  =   18.29       ALONGWIND DIM (M)  =   24.38

****************************************
   END OF CAVITY CALCULATIONS
****************************************


   ***************************************
   *** SUMMARY OF SCREEN MODEL RESULTS ***
   ***************************************

 CALCULATION      MAX CONC   DIST TO   TERRAIN
  PROCEDURE      (UG/M**3)   MAX (M)   HT (M)
 --------------  ----------  -------  -------
SIMPLE TERRAIN     22.76        20.      0.

BLDG. CAVITY-1     7.904        20.      --  (DIST = CAVITY LENGTH)

BLDG. CAVITY-2     10.54        17.      --  (DIST = CAVITY LENGTH)


***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
***************************************************
```